PROCEEDINGS

OF THE

AMERICAN ACADEMY

OF

ARTS AND SCIENCES.

NEW SERIES.
VOL. I.

WHOLE SERIES.
VOL. IX.

FROM MAY, 1873, TO MAY, 1874.

SELECTED FROM THE RECORDS.

BOSTON:
PRESS OF JOHN WILSON AND SON.
1874.

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AMERICAN ACADEMY

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VOL. IX.

PAPERS READ BEFORE THE ACADEMY.

I.

APPLICATIONS OF FRESNEL'S FORMULA FOR THE REFLECTION OF LIGHT.

By Edward C. Pickering.

Read, Oct. 14, 1873.

Part I. Theoretical.

One of the most beautiful applications of the Undulatory Theory was made by Fresnel, in deducing a formula for computing the amount of light reflected by the surface of a transparent medium. He showed that if the light was polarized in the plane of incidence, that the amount reflected would be $A = \frac{\sin^2 (i-r)}{\sin^2 (i+r)}$, while, if polarized in a plane perpendicular to it, the proportion would be $B = \frac{\text{tang}^2 (i-r)}{\text{tang}^2 (i+r)}$, i and r representing the angles of incidence and refraction respectively. Natural light may be regarded as composed of two equal beams polarized at right angles, hence the amount reflected $R = \frac{1}{2} (A + B) = \frac{1}{2} \left(\frac{\sin^2 (i-r)}{\sin^2 (i+r)} + \frac{\text{tang}^2 (i-r)}{\text{tang}^2 (i+r)}\right)$, a formula which may be applied to any special case, by substituting proper values for i and r. The value of A evidently increases as i varies from 0° to 90°. That of B, on the other hand, diminishes from 0° until $i + r = 90°$, when it equals 0, or at this angle, which is that of total polarization, all of the ray B is transmitted, all the reflected beam being polarized in the plane of incidence. When $i = 90°$, $A = 1$, $B = 1$, hence all the light is reflected.

When the light, instead of passing from the rare to the dense medium, goes in the other direction, the same amount of light is

reflected, as we merely make $n' = \frac{1}{n}$, and i becomes r, and r, i, the values of A and B being unchanged.

When $i = 0°$, or is infinitesimal, $A = \frac{\sin^2 (n-1)r}{\sin^2 (n+1)r} = \left(\frac{n-1}{n+1}\right)^2$ and $B = \left(\frac{n-1}{n+1}\right)^2$; hence the reflected ray $R = \left(\frac{n-1}{n+1}\right)^2$ and is unpolarized. Table I. gives the values of R for various values of n.

TABLE I.

Light reflected when $i = 0°$, or incident light normal to surface.

n	$\frac{1}{2}(A+B)$	n	$\frac{1}{2}(A+B)$
1.00	0.00	2.0	11.11
1.02	0.01	2.25	14.06
1.05	0.06	2.5	18.37
1.1	0.23	2.75	22.89
1.2	0.83	3.	25.00
1.3	1.70	4.	36.00
1.4	2.78	5.	44.44
1.5	4.00	5.83	50.00
1.6	5.33	10.	66.67
1.7	6.72	100.	96.08
1.8	8.16	∞	100.00
1.9	9.63		

The light therefore increases with n, being zero when $n = 1$, and 100 per cent, or all reflected when $r = \infty$.

This law also holds for other angles of incidence, and serves to explain many familiar phenomena. The brilliancy of the diamond is mainly due to its high index, causing it to reflect about 20 per cent of the light falling normally on it, while glass returns but 4 per cent.

The white color of fine powders is generally due to the light reflected from the faces of the minute crystals of which they are composed. Hence, immersing them in a liquid diminishes their brightness, since the relative index being reduced, less light is reflected. This is seen when snow is immersed in water, or when we write with wet chalk on a blackboard. In the last case, the relative index $= \frac{\text{index chalk}}{\text{index water}} = \frac{1.5}{1.33} = 1.167$, and 0.6 per cent only is reflected; while, when dry, the index is 1.5, and 4 per cent, or six times as much, is sent back. For the same reason, white lead is injured as an oil paint when adulterated with sulphate of baryta, which, although as white, has an index of refraction of 1.68 instead of 1.9. The effect is to diminish the covering power, the light being transmitted instead of reflected, so that when applied as a paint more coats are needed. In the four cases, we have white lead,

dry, index $= 1.9$, reflects 9.6 per cent; white lead in oil, index 1.27, reflection 1.44; baryta, dry, index 1.68, reflection 6.9; baryta in oil, index 1.12, reflection 0.32. Accordingly, when dry, either reflects enough light, while, when surrounded with oil, the baryta is nearly transparent. Baryta, or even carbonate of lime, may, however, be used as a water color, since either has a large enough index compared with air. With colored paints, on the other hand, we wish to destroy the reflected light which, united with the natural color of the pigment, deadens it. Hence oil colors are more brilliant than water, and the latter brighter when wet than dry. Numerous other facts may be explained in the same way, as that varnishing increases the brilliancy of pebbles and wood; in diamond mines the rough gem is distinguished from the quartz pebbles, which it resembles, by immersing it in water; and paper is rendered transparent by oiling it.

Let us next discuss the case where n is very nearly unity, or $n = 1 + dn$. Since $\sin i = n \sin r$, $\cos i \, di = \sin r \, dn$, and $di = \frac{\sin r}{\cos i} dn = \text{tang } i \, dn$. Now $i - r = di$, and $i + r = 2 i + di = 2 i$ $\therefore$ $A = \left(\frac{\text{tang } i \, dn}{\sin 2 i}\right)^2 = \left(\frac{dn}{2 \cos^2 i}\right)^2 = \frac{dn^2}{4} \sec^4 i = \frac{dn^2}{4} (1 + \text{tang}^2 i)^2$, and $B = \left(\frac{\text{tang } i \, dn}{\text{tang } 2 i}\right)^2 = \left(\frac{dn}{2} (1 - \text{tang}^2 i)\right)^2 = \frac{dn^2}{4} (1 - \text{tang}^2 i)^2$, and the degree of polarization of the reflected beam, or $\frac{A - B}{A + B} = \frac{2 \text{ tang}^2 i}{1 + \text{tang}^4 i} = \frac{2 \sin^2 i}{2 - \sin 2 i}$.

Of course the absolute amount of light reflected when dn is infinitesimal is zero, unless $i = 90°$; but as commonly we only wish to compare the relative amounts when dn is small, it is generally best to neglect the constant term $\frac{di^2}{4}$, and use $A = (1 + \text{tang}^2 i)^2 = \sec^4 i$, and $B = (1 - \text{tang}^2 i)^2 = \left(\frac{\text{tang } i}{\text{tang } 2 i}\right)^2$. When di varies, the reflection is proportional to its square, or to dn^2. When $i = 0$, A, B, and R become equal to 1; hence this forms an excellent unit, with which the amount reflected at other angles of incidence may be compared.

Table II. gives the amount of light for various angles of incidence. Column 1 gives i, the angle of incidence; column 2 gives A; column 3, B; column 4, $\frac{1}{2}(A + B)$, or the amount of light reflected; and column 5, the degree of polarization.

This table is of interest, as it is applicable to all cases where the two surfaces have nearly the same index. It will be noticed that the angle of total polarization is 45°, and that as i approaches 90°, the amount of light reflected becomes very great.

TABLE II.

Light reflected when n is near unity, or equals $1 + dn$.

i	A	B	$\frac{1}{2}(A+B)$	$\frac{A-B}{A+B}$
0°	1.000	1.000	1.000	0.0
5	1.015	.985	1.000	1.5
10	1.063	.939	1.001	6.2
15	1.149	.862	1.005	14.3
20	1.282	.752	1.017	26.0
25	1.482	.612	1.047	41.5
30	1.778	.444	1.111	60.0
35	2.221	.260	1.240	79.1
40	2.904	.088	1.496	94.5
45	4.000	.000	2.000	100.0
50	5.857	.176	3.016	94.5
55	9.239	1.081	5.160	79.1
60	16.000	4.000	10.000	60.0
65	31.346	12.952	22.149	41.5
70	73.079	42.884	57.981	26.0
75	222.85	167.16	195.00	14.3
80	1099.85	971.21	1035.53	6.2
85	17330.64	16808.08	17069.86	1.5
90	∞	∞	∞	0.0

The most important application of Fresnel's formula is to the case of glass, where n somewhat exceeds 1.5. Brewster calculated such a table for $n = 1.525$, which is published in Phil. Trans. 1830, p. 143. A much more complete table is given below (Tables III., IV., and V.)

TABLE III.

Light reflected when $n = 1.55$.

i	r	A	B	dA	dB	$\frac{1}{2}(A+B)$	$\frac{A-B}{A+B}$
0°	0° 0′.0	4.65	4.65	.130	.130	4.65	0.0
5	3° 13′.4	4.70	4.61	.131	.129	4.65	1.0
10	6° 25′.9	4.84	4.47	.135	.126	4.66	4.0
15	9° 36′.7	5.09	4.24	.141	.121	4.66	9.1
20	12° 44′.8	5.45	3.92	.150	.114	4.68	16.4
25	15° 49′.3	5.95	3.50	.161	.105	4.73	25.9
30	18° 49′.1	6.64	3.00	.175	.094	4.82	37.8
35	21° 43′.1	7.55	2.40	.191	.081	4.98	51.7
40	24° 30′.0	8.77	1.75	.210	.066	5.26	66.7
45	27° 8′.5	10.38	1.08	.233	.049	5.73	81.2
50	29° 37′.1	12.54	.46	.263	.027	6.50	92.9
55	31° 54′.2	15.43	.05	.303	.007	7.74	99.3
60	33° 58′.1	19.35	.12	.342	−.013	9.73	98.8
65	35° 47′.0	24.69	1.13	.375	−.032	12.91	91.2
70	37° 19′.1	31.99	4.00	.400	−.050	18.00	77.7
75	38° 32′.9	42.00	10.38	.410	−.060	26.19	61.8
80	39° 26′.8	55.74	23.34	.370	−.069	39.54	41.0
85	39° 59′.6	74.52	49.03	.250	−.061	61.77	20.6
90	40° 10′.7	100.00	100.00	.000	−.000	100.00	0.0

Angle of total polarization = 57° 10′.3, A = 16.99.

TABLE IV.

Light reflected when $n = 1.55$, and i is near angle of total polarization.

i	B	dB
50°	.463	+.027
51	.359	+.023
52	.263	+.019
53	.179	+.015
54	.119	+.011
55	.053	+.007
56	.016	+.003
57	.000	—.001
58	.008	—.005
59	.037	—.009
60	.120	—.013

TABLE V.

Light reflected when $n = 1.55$, and i is near 90°.

i	A	B	dA	dB	i	A	B	dA	dB
70° 0′	31.99	4.00	.400	.050	86° 0′	79.02	56.62	.209	.055
71 0	33.21	4.94	.405	.052	86 10	79.80	57.98	.201	.053
72 0	35.24	6.03	.409	.054	86 20	80.58	59.39	.193	.052
73 0	37.38	7.28	.411	.056	86 30	81.39	60.82	.187	.050
74 0	39.64	8.72	.412	.058	86 40	82.18	62.29	.178	.049
75 0	42.00	10.38	.410	.060	86 50	82.98	63.79	.171	.047
76 0	44.49	12.31	.406	.062	87 0	83.80	65.32	.163	.046
77 0	47.08	14.54	.400	.064	87 10	84.63	66.89	.155	.045
78 0	49.80	17.07	.392	.066	87 20	85.46	68.49	.147	.043
79 0	52.66	20.00	.383	.068	87 30	86.31	70.14	.140	.041
80 0	55.74	23.34	.370	.069	87 40	87.15	71.82	.133	.040
80 30	57.36	25.20	.361	.069	87 50	88.01	73.55	.125	.038
81 0	59.04	27.18	.353	.069	88 0	88.88	75.31	.118	.036
81 30	60.77	29.33	.342	.068	88 10	89.76	77.11	.109	.034
82 0	62.60	31.57	.331	.068	88 20	90.64	78.96	.099	.032
82 30	64.41	34.04	.320	.067	88 30	91.54	80.75	.090	.030
83 0	66.30	36.64	.310	.067	88 40	92.44	82.79	.081	.027
83 30	68.27	39.43	.297	.066	88 50	93.35	84.76	.072	.025
84 0	70.29	42.41	.284	.065	89 0	94.28	86.79	.063	.022
84 30	72.37	45.61	.267	.063	89 10	95.21	88.88	.054	.019
85 0	74.52	49.03	.250	.061	89 20	96.16	91.00	.045	.015
85 10	75.25	50.23	.244	.060	89 30	97.11	93.18	.035	.012
85 20	75.99	51.45	.238	.059	89 40	98.06	95.40	.024	.008
85 30	76.74	52.69	.232	.058	89 50	99.02	97.66	.012	.004
85 40	77.49	53.96	.224	.057	90 0	100.00	100.00	.000	.000
85 50	78.25	55.28	.217	.056					

for $n = 1.55$, the letters having the same meaning as in Table II. Columns 5 and 6 furnish a means of determining A and B for any other value of n. They represent the change in these quantities, for a

change of n of .01. For instance, the value of A for $n = 1.55$, $i = 25°$, is 5.95, as given in the table, and it increases .161 for every increase of .01 in n. Thus, when $n = 1.50$, $A = 5.15$. In the same way B then equals 2.98. These values are of course only approximate, and are most correct for values of n between 1.50 and 1.55. In the same way, Table IV. gives the corresponding values of B, and $d\,B$ for angles near that of total polarization, and Table V. A and B for values near 90°.

In practice we commonly have to deal with some even number of parallel surfaces, especially several plates of glass. It is therefore important to discuss this case for various values of i, and of the number of plates. When a surface reflects the fraction A of the light, the transmitted portion equals $1 - A$; and if there is no internal reflection, the second surface will reflect the same proportion, or $A\,(1 - A)$, and transmit $(1 - A)^2$. In the same way, m surfaces will transmit $(1 - A)^m$. But practically, of the light reflected by the second surface, part will be turned back by the first, so that the total transmitted ray equals $\frac{1 - A}{1 + A}$, and that reflected $\frac{2\,A}{1 + A}$. In the same way it may readily be proved that for m surfaces the transmitted ray equals $\frac{1 - A}{1 + (m - 1)\,A}$, and the reflected ray $\frac{m\,A}{1 + (m - 1)\,A}$. Table VI. gives the values of i, A, and B, the amount of light reflected, the amount polarized by reflection, and that polarized by refraction, for 1, 2, 8, and 20 surfaces. The amount refracted of course equals 100 minus that reflected. The absorbed light is here neglected, as it is comparatively small, and varies with each specimen of glass.

The following conclusions are readily drawn from an examination of the numbers in Table VI., or, better, from the curves given in Figs. 1 and 2. In all the figures accompanying this paper, ordinates represent percentages, and abscissas angles of incidence. In Fig. 1, the four highest curves represent the polarization of the beams reflected by 1, 2, 8, and 20 surfaces. The other four curves give the corresponding refracted beams. Fig. 2 gives all the curves of Table VI., relating to twenty surfaces; the five curves corresponding to A, B, the intensity of the refracted beam, and the polarization of both the reflected and refracted beams. When $i = 0$, both the reflected and refracted beams are unpolarized. With ten plates of glass about half the light is reflected, the transmitted ray being but little brighter than that reflected. With 1 or 2 surfaces the reflected beam increases as i increases; with 8 surfaces it remains nearly constant up to 50°; while with 20 surfaces a marked diminution is perceived. This very remark-

TABLE VI. — Light reflected by 1, 2, 8, and 20 Surfaces.

	1 Surface.					2 Surfaces, 1 Plate.				
i	*A*	*B*	Reflect.	Per ct. Polariz.		*A*	*B*	Reflect.	Per ct. Polariz.	
				Reflct.	Refrct.				Reflct.	Refrct.
0°	4.6	4.6	4.6	0.0	0.0	8.8	8.8	8.8	0.0	0.0
5	4.7	4.6	4.6	1.0	0.0	9.0	8.7	8.8	1.0	0.1
10	4.8	4.5	4.7	4.0	0.2	9.2	8.6	8.9	4.1	0.4
15	5.1	4.2	4.7	9.1	0.4	9.8	8.1	8.9	9.2	0.9
20	5.4	3.9	4.7	16.4	0.8	10.4	7.5	8.9	16.3	1.6
25	5.9	3.5	4.7	25.9	1.3	11.1	6.7	8.9	25.4	2.5
30	6.6	3.0	4.8	37.8	1.9	12.5	5.8	9.1	36.4	3.6
35	7.5	2.4	5.0	51.7	2.7	14.2	4.7	9.4	49.3	5.2
40	8.8	1.7	5.3	66.7	3.7	16.4	3.5	10.0	64.0	7.2
45	10.4	1.1	5.7	81.2	4.9	19.0	2.1	10.6	80.1	9.4
50	12.5	0.5	6.5	92.9	6.5	22.4	0.5	11.4	95.6	12.5
55	15.4	0.1	7.7	99.3	8.3	26.9	0.1	14.0	99.3	15.6
57	17.0	0.0	8.5	100.0	9.3	29.1	0.0	14.5	100.0	17.0
60	19.3	0.1	9.7	98.8	10.6	32.4	0.2	16.3	98.8	19.2
65	24.7	1.1	12.9	91.2	13.5	38.4	2.5	20.4	87.7	23.2
70	32.0	4.0	18.0	77.7	17.1	48.5	7.7	28.1	72.6	28.4
75	42.0	10.4	26.2	61.8	21.9	59.6	19.7	39.1	52.2	33.2
80	55.7	23.3	39.5	41.0	26.8	71.7	38.0	54.8	30.7	37.2
82	62.6	31.6	47.1	32.8	29.8	77.1	48.3	62.7	22.7	38.6
84	70.3	42.4	56.3	24.7	32.1	82.7	60.2	71.4	15.7	39.6
85	74.5	49.0	61.8	20.6	33.3	85.4	68.5	75.8	12.6	40.0
86	79.0	56.6	67.2	16.5	34.8	88.2	72.5	80.3	9.8	40.4
87	83.8	65.3	74.6	12.4	36.3	91.4	79.2	85.3	7.0	40.8
88	88.9	75.3	82.1	8.2	37.9	94.1	86.1	90.1	4.4	41.0
89	94.3	86.8	90.5	4.1	39.6	96.9	92.9	94.9	2.0	41.1
90	100.0	100.0	100.0	0.0	41.2	100.0	100.0	100.0	0.0	41.2
	8 Surfaces, 4 Plates.					20 Surfaces, 10 Plates.				
0°	28.3	28.3	28.3	0.0	0.0	49.4	49.4	49.4	0.0	0.0
5	28.6	28.0	28.3	0.9	0.3	49.7	49.1	49.4	0.6	0.6
10	29.2	27.4	28.3	3.4	1.2	50.4	48.3	49.3	2.1	2.1
15	30.2	26.3	28.3	7.4	2.7	51.5	46.9	49.2	4.7	4.6
20	31.9	24.5	28.2	13.1	5.1	53.3	44.9	49.1	8.5	8.3
25	33.9	22.4	28.2	20.3	7.9	55.8	42.2	49.0	13.9	13.4
30	36.8	19.3	28.1	29.2	11.4	58.7	38.2	48.4	21.2	19.7
35	39.5	16.5	28.0	41.1	16.0	62.2	33.0	47.6	30.9	27.9
40	43.7	12.1	27.9	56.4	21.8	65.9	26.3	46.2	42.4	36.7
45	48.3	7.4	27.9	73.3	28.1	69.8	17.1	43.4	55.9	46.6
50	53.5	3.2	28.3	88.7	35.1	74.1	8.5	41.3	79.5	56.4
55	59.4	0.5	30.0	98.3	42.0	78.4	1.0	39.7	97.5	64.5
57	62.1	0.0	31.0	100.0	45.0	80.4	0.0	40.2	100.0	67.2
60	66.3	1.7	34.0	95.0	48.9	82.8	2.4	43.6	94.5	71.0
65	72.5	7.6	40.0	81.0	54.1	86.9	18.6	52.7	64.7	72.2
70	79.0	25.0	52.0	51.9	56.8	90.4	45.5	68.0	33.0	70.0
75	85.3	48.2	66.7	27.8	55.8	93.5	69.9	81.7	11.3	64.6
80	91.0	71.1	81.0	12.3	52.6	96.2	85.9	91.0	5.6	57.1
82	93.1	79.0	86.0	8.2	50.5	97.1	90.3	93.7	3.6	54.0
84	95.0	85.5	90.2	5.2	48.6	97.9	93.7	95.8	2.2	50.9
85	95.5	88.4	92.0	3.8	47.5	98.3	95.1	96.7	1.6	49.3
86	96.8	91.3	94.0	2.6	46.2	98.7	96.4	97.5	1.2	47.7
87	97.6	93.8	95.7	1.7	45.0	99.0	97.4	98.2	0.8	46.1
88	98.4	96.1	97.2	1.1	43.8	99.4	98.4	98.9	0.5	44.5
89	99.2	98.1	98.6	0.5	42.5	99.7	99.2	99.4	0.2	42.9
90	100.0	100.0	100.0	0.0	41.2	100.0	100.0	100.0	0.0	41.2

able result may be expressed by saying that 10 plates of glass transmit more light obliquely than normally. The appearance to the eye confirms this result, but it deserves a careful photometric proof. At 57° the reflected ray is of course, in all cases, totally polarized; but at other angles the amount of polarization is greater the less the number of surfaces, instead of the contrary, as might have been anticipated.

With the refracted ray quite a different law holds. For 1 surface the polarization increases from 0° to 90°; with 2 surfaces it becomes sensibly constant near 90°; while with a larger number a distinct maximum is obtained. It is commonly supposed that the greatest effect is obtained at the angle of total polarization. But the maximum is sensibly beyond this, unless a very large number of plates is employed; and hence it seems probable that a bundle of plates, polarizing by refraction, would give the best results if set at a greater angle than 57°, as 65° or 70°. The transmitted ray, however, diminishes rapidly for large angles of incidence. A very large number of plates is required to render the polarization nearly complete, which accounts for the light always remaining when even the best polariscopes by refraction are crossed. At 90° all the refracted beams are polarized by the same amount of 41.2 per cent. Or, at grazing incidence, the amount of polarization is independent of the number of plates, one polarizing as completely as a hundred. This number 41.2 may be obtained as follows. Differentiate the value of A in terms of i and r, and make $i = 90°$, when the refracted beam will equal $1 - A = 4 \tan r \, di = 3.376 \, di$, since when $i = 90°$, $r = 40° \, 10'.7$. In the same way $1 - B = \frac{8.}{\sin 2r} di = 8.115 \, di$, and applying to them the formulæ for the polarization of the refracted beam, we find it equal to 41.2.

The last portion of Table VI. was determined in part by graphical interpolation, and hence the results are less accurate than those of the other tables. It is believed, however, that the errors are much less than those of any known method of testing them experimentally, and hence give all the accuracy needed for practical purposes.

To show how far these effects are due to the internal reflection, Table VII. has been computed for the same number of surfaces, supposing that no secondary reflection takes place. The first column gives the angle of incidence, the next three the polarization of the reflected, and the last three that of the refracted beam. A comparison with Table VI. shows that while the reflected beam is affected but little, a great change takes place in the transmitted light. A simple method of expressing the difference between Tables VI. and VII. is to

say that, in the former, the transmitted rays are computed by the formula $\frac{1-a}{1+(m-1)a}$, and in the latter, where the internal reflection is neglected, by the formula $(1-a)^m$.

TABLE VII.

Polarization, supposing there is no internal reflection.

Reflected Beam.				Refracted Beam.		
i	2.	8.	20.	2.	8.	20.
0°	0.0	0.0	0.0	0.0	0.0	0.0
30	87.0	82.8	24.1	3.8	15.2	36.5
45	80.3	75.1	64.0	9.9	37.6	75.6
57	100.0	100.0	100.0	18.4	63.2	95.2
70	74.5	54.8	28.4	33.2	88.1	99.8
80	32.2	6.3	0.0	50.0	97.6	100.0
90	0.0	0.0	0.0	70.1	99.8	100.0

PART II. EXPERIMENTAL.

To test the above conclusions, two experimental methods may be employed. First, by means of a photometer, to determine the amount of light in any given case; and, secondly, by means of a polarimeter, to determine the percentage of polarization of the reflected and refracted rays. The latter method has been employed in the following experiments. The instrument commonly used to measure the amount of polarization was invented by Arago, and is called a polarimeter. It consists of a Nicol's prism and Savart's plates, in front of which are several glass plates, free to turn, and carrying an index which moves over a graduated circle, thus showing the angle through which they have been rotated. The prism and plates form a Savart's polariscope, which gives colored bands with either light or dark centre, according as the plane of the prism is parallel or perpendicular to the plane of polarization. When the plates are so placed that the light passes through them normally, they have no effect on it; but when turned, they polarize it in a plane parallel to the axis of rotation, and by an amount dependent on the angle. Let the instrument be so set that the axis of rotation shall be perpendicular to the plane of polarization, and the plates set at zero. The bands will then be visible, the centre one being bright. As the plates are turned, the bands become fainter, until their polarization neutralizes that originally present in the beam; beyond this point the bands reappear dark-centred. The amount of polariza-

tion is thus readily determined, by turning the plates until the bands disappear, when the angle is reduced to percentages by means of a table. The difficulty of computing this table is, however, the real objection to the use of this instrument. It may be determined by the formulæ given in the first part of this paper; but it of course then fails to prove them. Moreover, no account is taken of imperfect transparency, dust on the surface, and other sources of error. An excellent way of forming this table experimentally is to view through the instrument a beam of light totally polarized. If now the plane of polarization of the beam is changed, the percentage of polarization will alter, being zero when it is inclined 45° to the axis of the plates, and wholly polarized at an angle of 0° or 90°. At any angle a, the beam may be regarded as composed of two, $\cos^2 a$ polarized vertically, and $\sin^2 a$ polarized horizontally. The percentage of polarization will therefore equal $\frac{\cos^2 a - \sin^2 a}{\cos^2 a + \sin^2 a} = \cos 2\,a$, from which the polarization corresponding to any given angle is readily determined.

The result of such a comparison is given in Table VIII. Four series of observations were taken, of which the numbers obtained are given in Table XIII. From them curves were constructed, with angles of incidence as abscissas and percentages of polarization as ordinates. A curve was next drawn, coinciding with them as nearly as possible, and its ordinates are given in Table VIII., column 3; the angles of incidence are given in the first column, and the theoretical polarization in the second column of the same table. Column 4 gives the differences, and from it we see that, while the agreement is very close between 0° and 60°, above this point a marked variation is perceptible. This deviation will be further discussed in connection with Table XIII. and Fig. 8.

TABLE VIII.

Table for Arago's Polarimeter.

i	Theoretical.	Empirical.	Difference.
0°	0.0	0.0	0.0
20	5.1	5.0	−0.1
30	11.4	13.0	1.6
40	21.8	23.5	1.7
50	35.1	37.0	1.9
55	42.0	43.0	1.0
60	48.9	49.0	0.1
65	54.1	57.5	3.4
70	56.3	63.5	7.2
75	55.8	67.0	11.2
80	52.6	72.0	19.4

To avoid the defects of the above instrument, the following arrangement has been employed. A brass tube, $A B$, Fig. 3, about a foot long, is closed at one end by a double image prism, B; and at the other by a rectangular aperture, A, of such a width that its two images, as in the Arago polariscope, shall be in contact, but not overlapping. To the prism is attached a Nicol's prism, free to turn, and carrying an index, moving over a graduated circle, which shows how far it has been rotated. The tube is then mounted, so that it can be set at any altitude or azimuth, or rotated around its own axis, and three graduated circles serve to measure these quantities. In the instrument as actually constructed (Fig. 4), the whole is supported on an upright, which terminates below in a large screw, C, by which it may be attached to a post or tree, when used out of doors. A tube slips over this, which carries a cross-piece forming a T, and through the top of this passes the end of a second T, through the end of which the polarimeter slides. Three of these tubes are graduated to show the azimuth and altitude of the polarimeter tube, and the amount it is turned around its own axis.

The working of the instrument is as follows. If the Nicol's prism is removed, and the light unpolarized, the two images of the aperture at the end will be equally brilliant. If now the Nicol's prism is replaced and turned, the images will vary in brightness, alternately disappearing at intervals of 90°. If the light is polarized, one image will in general be brighter than the other; but by turning the Nicol's prism, certain positions will always be found in which the two images will be equal. The percentage of polarization is then readily determined from the angle through which the prism has been turned. To determine the law which connects these two, let the plane of polarization be vertical, and the line of junction of the two images parallel to it. Then call A and B the brightness of the two images respectively, in which case the polarization $p = \frac{A - B}{A + B}$. If the prism is turned through an angle v, one image will have a brightness $A \sin^2 v$, the other $B \cos^2 v$; and if they are equal, $A \sin^2 v = B \cos^2 v$, hence $p = \frac{\cos^2 v - \sin^2 v}{\cos^2 v + \sin^2 v} = \cos 2 v$. The amount of polarization is then very simply found by turning the Nicol until the images are equal, then reading the angle, doubling it, and taking the cosine. Evidently there are four positions of equality of the image; and in the following experiments all four were observed, reading to tenths of a degree, and the mean taken. To make the reduction, Table IX. is employed, in which the columns headed p give the percentage of polarization corresponding to the angle a.

TABLE IX.

Table for Polarimeter: $p = \cos 2a \times 100$.

a	p	a	p	a	p	a	p
0.0°	100.00	5.0°	98.48	10.0°	93.97	15.0°	86.60
0.1	100.00	5.1	98.42	10.1	93.85	15.1	86.43
0.2	100.00	5.2	98.36	10.2	93.73	15.2	86.25
0.3	99.99	5.3	98.29	10.3	93.61	15.3	86.07
0.4	99.99	5.4	98.23	10.4	93.48	15.4	85.90
0.5	99.98	5.5	98.16	10.5	93.36	15.5	85.72
0.6	99.98	5.6	98.10	10.6	93.23	15.6	85.54
0.7	99.97	5.7	98.03	10.7	93.11	15.7	85.35
0.8	99.96	5.8	97.96	10.8	92.98	15.8	85.17
0.9	99.95	5.9	97.89	10.9	92.85	15.9	84.99
1.0	99.94	6.0	97.81	11.0	92.72	16.0	84.80
1.1	99.93	6.1	97.74	11.1	92.59	16.1	84.62
1.2	99.91	6.2	97 67	11.2	92.45	16.2	84.43
1.3	99.90	6.3	97.59	11.3	92.32	16.3	84.24
1.4	99.88	6.4	97.51	11.4	92.19	16.4	84.06
1.5	99.86	6.5	97.44	11.5	92.05	16.5	83.87
1.6	99.84	6.6	97.36	11.6	91.91	16.6	83.68
1.7	99.82	6.7	97.28	11.7	91.77	16.7	83.48
1.8	99.80	6.8	97.20	11.8	91.64	16.8	83.29
1.9	99.78	6.9	97.11	11.9	91.50	16.9	83.10
2.0	99.76	7.0	97.03	12.0	91.35	17.0	82.90
2.1	99.73	7.1	96.94	12.1	91.21	17.1	82.71
2.2	99.70	7.2	96.86	12.2	91.07	17.2	82.51
2.3	99.68	7.3	96.77	12.3	90.92	17.3	82.31
2.4	99.65	7.4	96.68	12.4	90.78	17.4	82.11
2.5	99.62	7.5	96.59	12.5	90.63	17.5	81.91
2.6	99.59	7.6	96.50	12.6	90.48	17.6	81.71
2.7	99.56	7.7	96.41	12.7	90.33	17.7	81.51
2.8	99.53	7.8	96.32	12.8	90.18	17.8	81.31
2.9	99.49	7.9	96.23	12.9	90.03	17.9	81.11
3.0	99.45	8.0	96.13	13.0	89.88	18.0	80.90
3.1	99.42	8.1	96.03	13.1	89.73	18.1	80.70
3.2	99.38	8.2	95.93	13.2	89.57	18.2	80.49
3.3	99.34	8.3	95.83	13.3	89.41	18.3	80.28
3.4	99.30	8.4	95.73	13.4	89.26	18.4	80.07
3.5	99.25	8.5	95 63	13.5	89.10	18.5	79.86
3.6	99.22	8 6	95.53	13 6	88.94	18.6	79.65
3.7	99.17	8.7	95.42	13.7	88.78	18.7	79.44
3.8	99.12	8.8	95.32	13.8	88.62	18.8	79.23
3.9	99.07	8.9	95.21	13.9	88.46	18.9	79.02
4.0	99.03	9.0	95.11	14.0	88.29	19.0	78.80
4.1	98.98	9.1	95.00	14.1	88.13	19.1	78.59
4.2	98.93	9.2	94.89	14.2	87.96	19.2	78.37
4.3	98.88	9.3	94.78	14.3	87.80	19.3	78.15
4.4	98.82	9.4	94.66	14.4	87.63	19.4	77.93
4.5	98.77	9.5	94.55	14.5	87.46	19.5	77.71
4.6	98.72	9.6	94.44	14.6	87.29	19.6	77.49
4.7	98.66	9.7	94.32	14.7	87.12	19.7	77.27
4.8	98.60	9.8	94.21	14.8	86.95	19.8	77.05
4.9	98.54	9.9	94.09	14.9	86.78	19.9	76.83

TABLE IX., — *continued.*

Table for Polarimeter: $p = \cos 2a \times 100$.

a	p	a	p	a	p	a	p
20.0°	76.60	25.0°	64.28	30.0°	50.00	35.0°	34.20
20.1	76.38	25.1	64.01	30.1	49.70	35.1	33.87
20.2	76.15	25.2	63.74	30.2	49.39	35.2	33.54
20.3	75.93	25.3	63.47	30.3	49.09	35.3	33.22
20.4	75.70	25.4	63.20	30.4	48.79	35.4	32.89
20.5	75.47	25.5	62.93	30.5	48.48	35.5	32.56
20.6	75.24	25.6	62.66	30.6	48.17	35.6	32.23
20.7	75.01	25.7	62.39	30.7	47.87	35.7	31.90
20.8	74.78	25.8	62.11	30.8	47.56	35.8	31.56
20.9	74.55	25.9	61.84	30.9	47.25	35.9	31.23
21.0	74.31	26.0	61.57	31.0	46.95	36.0	30.90
21.1	74.08	26.1	61.29	31.1	46.64	36.1	30.57
21.2	73.85	26.2	61.01	31.2	46.33	36.2	30.24
21.3	73.61	26.3	60.74	31.3	46.02	36.3	29.90
21.4	73.37	26.4	60.46	31.4	45.71	36.4	29.57
21.5	73.13	26.5	60.18	31.5	45.40	36.5	29.24
21.6	72.90	26.6	59.90	31.6	45.09	36.6	28.90
21.7	72.66	26.7	59.62	31.7	44.78	36.7	28.57
21.8	72.42	26.8	59.34	31.8	44.46	36.8	28.23
21.9	72.18	26.9	59.06	31.9	44.15	36.9	27.90
22.0	71.93	27.0	58.78	32.0	43.84	37.0	27.56
22.1	71.69	27.1	58.50	32.1	43.52	37.1	27.23
22.2	71.45	27.2	58.21	32.2	43.21	37.2	26.89
22.3	71.20	27.3	57.93	32.3	42.89	37.3	26.56
22.4	70.96	27.4	57.63	32.4	42.58	37.4	26.22
22.5	70.71	27.5	57.36	32.5	42.26	37.5	25.88
22.6	70.46	27.6	57.07	32.6	41.94	37.6	25.54
22.7	70.21	27.7	56.78	32.7	41.63	37.7	25.21
22.8	70.97	27.8	56.50	32.8	41.31	37.8	24.87
22.9	69.72	27.9	56.21	32.9	40.99	37.9	24.53
23.0	69.47	28.0	55.92	33.0	40.67	38.0	24.16
23.1	69.21	28.1	55.63	33.1	40.35	38.1	23.85
23.2	68.96	28.2	55.34	33.2	40.03	38.2	23.51
23.3	68.71	28.3	55.05	33.3	39.71	38.3	23.17
23.4	68.45	28.4	54.76	33.4	39.39	38.4	22.83
23.5	68.20	28.5	54.46	33.5	39.07	38.5	22.49
23.6	67.94	28.6	54.17	33.6	38.75	38.6	22.15
23.7	67.69	28.7	53.88	33.7	38.43	38.7	21.81
23.8	67.43	28.8	53.58	33.8	38.11	38.8	21.47
23.9	67.17	28.9	53.29	33.9	37.78	38.9	21.13
24.0	66.91	29.0	52.99	34.0	37.46	39.0	20.79
24.1	66.65	29.1	52.70	34.1	37.14	39.1	20.45
24.2	66.39	29.2	52.40	34.2	36.81	39.2	20.11
24.3	66.13	29.3	52.10	34.3	36.49	39.3	19.77
24.4	65.87	29.4	51.80	34.4	36.16	39.4	19.42
24.5	65.61	29.5	51.50	34.5	35.84	39.5	19.08
24.6	65.34	29.6	51.20	34.6	35.51	39.6	18.74
24.7	65.08	29.7	50.90	34.7	35.18	39.7	18.39
24.8	64.81	29.8	50.60	34.8	34.86	39.8	18.05
24.9	64.55	29.9	50.30	34.9	34.53	39.9	17.71

TABLE IX., — *continued.*

Table for Polarimeter: $p = \cos 2a \times 100$.

a	p	a	p	a	p	a	p
40.0°	17.36	41.3°	12.88	42.6°	8.37	43.8°	4.19
40.1	17.02	41.4	12.53	42.7	8.02	43.9	3.84
40.2	16.68	41.5	12.19	42.8	7.67	44.0	3.49
40.3	16.33	41.6	11.84	42.9	7.32	44.1	3.14
40.4	15.99	41.7	11.49	43.0	6.98	44.2	2.79
40.5	15.64	41.8	11.15	43.1	6.63	44.3	2.44
40.6	15.30	41.9	10.80	43.2	6.28	44.4	2.09
40.7	14.95	42.0	10.45	43.3	5.93	44.5	1.74
40.8	14.61	42.1	10.11	43.4	5.58	44.6	1.40
40.9	14.26	42.2	9.76	43.5	5.23	44.7	1.05
41.0	13.92	42.3	9.41	43.6	4.88	44.8	0.70
41.1	13.57	42.4	9.06	43.7	4.54	44.9	0.35
41.2	13.23	42.5	8.72				

Evidently when the light is unpolarized, the angle will be 45°; when totally polarized, 0°. We must now determine the effect when the line of junction is not parallel to the plane of polarization, but inclined at an angle w. The two images will in this case have a brightness $(A \cos^2 w + B \sin^2 w)$, and $(A \sin^2 w + B \cos^2 w)$. Hence the apparent polarization $p' = \frac{(A \cos^2 w + B \sin^2 w) - (A \sin^2 w + B \cos^2 w)}{(A \cos^2 w + B \sin^2 w) + (A \sin^2 w + B \cos^2 w)} = \frac{A-B}{A+B} \cos 2w = p \cos 2w$. Hence, if the line of junction is not parallel to the plane of polarization, the observations must be reduced by dividing by $\cos 2w$. Evidently if $w = 45°$, the light appears to be unpolarized. The above discussion suggests a means of determining the direction of the plane of polarization. Make two observations of the amount of polarization, turning the polarimeter 45°. Then call p, p', p'', the true and the observed polarization in the two cases, and w the unknown angle between the line of junction in its first position and the plane of polarization. Having given p' and p'', we wish to determine p and w. Evidently $p' = p \cos 2w$, and $p'' = p \cos 2(45° - w) = p \sin 2w$. Taking their quotient gives $\text{tang } 2w = \frac{p''}{p'}$, and the sum of their squares gives $p = \sqrt{p'^2 + p''^2}$. This method, though elegant theoretically, does not appear very accurate practically, as the plane is more accurately determined by covering the end of the polarimeter with a cap containing a plate of selenite, thus converting it into an Arago's polariscope. Then turn the tube until the two images have precisely the same color, when their line of junction will be inclined

45° to the plane of polarization. The plane may also be determined, more easily but less accurately, by removing the Nicol's prism, and turning the tube until the two images are equally bright, and adding 45° to the reading.

We next wish to determine the delicacy of this instrument in different parts of its scale. If the Nicol's prism is set at an angle v', differing slightly from its true value v, the brightness of the two images will be $A \sin^2 v'$ and $B \cos^2 v'$ respectively. Now it is commonly assumed that the difference in two such images will be perceptible, when the difference in brightness, divided by the brightness of either, equals a certain fraction $\frac{1}{a}$, in which a equals about 80. Now $\frac{1}{a} =$ $\frac{A \sin^2 v' - B \cos^2 v'}{A \sin^2 v'} = \frac{\sin^2 v' \cos^2 v - \cos^2 v' \sin^2 v}{\sin^2 v' \cos^2 v} = \frac{4 \sin (v + v') \sin (v' - v)}{\sin^2 2 v}$; hence, since v is substantially equal to v', $\frac{1}{a} = \frac{4 \sin (v' - v)}{\sin 2 v} = \frac{4\, dv}{\sin 2 v}$; again, since $p = \cos 2 v$, $dp = -2 \sin 2 v\, dv$, and $dp = \frac{1 - p^2}{2 a} = \frac{\sin^2 2 v}{2 a}$, from which the error in the result for any unobserved difference in brightness of the two images is readily determined.

If $p = 0$, $dp = \frac{1}{2 a}$, its greatest value, which diminishes as the polarization increases, becoming zero when $p = 0$. Hence the greater the polarization, the more accurately it can be measured. If $a = 80$, $dp = \frac{1}{160}$ for its greatest value; hence the instrument should always give results within two-thirds of 1 per cent. Observation, however, shows that the error is much greater, a difference in brightness of $\frac{1}{80}$ being by no means perceptible. To determine this point, ten observations of a bright unpolarized cloud were taken, and gave a probable error of 1°.1, which corresponds to 3.8 per cent. The beam reflected from a plate of glass was then observed in the same way, and the probable error was found to be 0°.7, equal 1.0 per cent. As the polarization in this case was 87 per cent, the probable error should have been 3.8 $(1 - p^2) = 3\,8 \times 2.43 = 0.9$, a result agreeing very closely with the observed amount. As might be expected, the error varies also with the intensity of the light, so that a sheet of unpolarized paper gave a probable error of 5.2 per cent. To compare the absolute brightness in this case with that of the cloud, the polarimeter was directed towards the latter, and its aperture half covered by the paper. The prism was then turned until the dark image of the sky just equalled the bright image of the paper. The mean angle was then found to be 25°, whence the relative brightness of the two images was found to be

$\tan^2 25° = .21$. As each of the following observations is the mean of four, the probable error is reduced one-half.

The first series of observations were made on the light of the sky. The instrument was screwed into a post and levelled, the altitude and azimuth of the sun taken, and the instrument then directed towards the points to be observed. Most of these were in the same vertical plane with the sun, so that it was only necessary to determine their altitudes. The line of junction was then brought parallel to the plane of polarization; that is, turned until it was vertical, since it then lay in the plane passing through the sun. The four positions of the Nicol's prism, in which the two images were equally bright, were then observed, reading the angles to tenths of a degree, and taking the mean. The percentage of polarization was finally obtained from Table IX. In Table X., series 1 to 9 were taken at Waterville, N. H., in a valley at a height of about 1500 feet, surrounded by mountains about 4000 feet high. The air there may be regarded as very pure. Series 10 and 11 were taken upon the top of the building of the Institute of Technology, Boston. The first column in each case gives the altitude of the point observed, the second its distance from the sun, and the third the polarization corresponding to the mean of the four observations. It soon became evident that the polarization depended on the solar distance of the point under observation, and not on the altitude. This is more evident from Fig. 5, in which abscissas give the solar distances and ordinates the polarization of the above points.

TABLE X.

Sky Polarization.

Altitude.	Sun's Dist.	Polarization.
1. July 7. 6.45 A.M.		
—15	142	19.6
—30	126	38.9
—45	110	65.4
—60	95	64.9
2. July 7. 9.30 A.M.		
—20	112	66.2
—35	95	79.9
—50	80	68.1
—65	64	47.8
70	18	2.8
40	—18	2.1
25	—29	11.2
15	—40	19.8
90	85	16.9
—57	60	44.9
—47	70	64.5
—37	80	72.4
—33	83	76.9
—19	97	77.7
— 5	110	62.2
3. July 8. 7.05 A.M.		
—10	145	8.0
—20	135	16.4
—30	125	37.8
—40	115	50.9
4. July 10. 6.30 A.M.		
—15	149	18.4
—20	144	14.2
—30	133	28.6
—40	122	41.8
—50	111	55.0
—60	100	69.2
—70	90	78.8

TABLE X., — *continued.*

Sky Polarization.

Altitude.	Sun's Dist.	Polarization.
5. July 15. 6.40 P.M.		
30	22	4.2
40	32	13.2
50	42	20.5
60	53	31.9
70	63	46.0
80	73	65.0
90	84	69.2
—80	94	70.9
—70	104	62.7
—60	115	53.0
—50	125	33.6
—40	135	20.1
—30	146	8.5
—20	156	2.8
—12	165	—3.5
6. July 16. 6.30 P.M.		
20	12	1.4
30	22	1.7
40	33	10.8
50	44	16.7
7. July 20. 12.20 P.M.		
60	—8	7.0
50	—18	—1.0
40	—27	5.6
30	—36	11.5
8. July 30. 4.00 P.M.		
15	—21	—1.0
20	—15	—2.4
25	—9	—2.8
40	7	2.4
45	12	—2.4
50	17	2.1
60	28	6.6
—60	88	72.7
—50	98	69.7
—40	108	58.2
—30	119	48.2
—20	129	29.2
—10	139	21.5
9. July 30. 6.30 P.M.		
18	8	—2.8
18	8	—1.7
28	19	—0.8
38	29	2.1
48	40	11.8
58	50	25.9
—60	113	55.6
—50	123	41.8
—40	134	21.5
—30	144	14.6
—20	155	2.4
—10	165	—1.7
—20	156	—9.8
—30	146	—2.8
—40	137	6.3
10. Sept. 12. 9.15 A.M.		
5	—40	12.2
15	—30	9.8
25	—20	5.2
66	20	3.1
76	30	10.8
86	40	10.8
—88	50	22.8
—78	60	33.9
—68	70	43.8
—52	80	57.1
—47	85	59.8
—42	90	62.7
—36	95	62.9
—31	100	57.7
—26	105	56.5
—20	110	55.0
—15	115	49.4
—10	120	48.5
—5	125	37.1
—0	130	31.2
11. Sept. 12. 6.00 P.M.		
—8	170	2.8
—19	160	7.7
—29	150	12.2
—40	140	23.8
—50	130	37.1
—61	120	51.5
89	90	79.0
58	60	47.2
48	50	29.9
37	40	19.1
27	30	10.1
16	20	5.6
6	10	1.7

Before discussing these observations further, it seemed desirable to determine the polarization of other parts of the atmosphere not lying in the same vertical plane with the sun. Moreover, as the polarization of points at equal distances from the sun should be compared, the polarimeter was so mounted that its principal axis would pass through the

sun. The two graduated circles would then give solar distances, and the angle from the vertical plane through the sun, instead of altitudes and azimuths. The second of these angles will be called the meridian distance, and will be regarded as positive to the right, and negative to the left of the sun. Of course, the direction of the axis should continually change, so as to follow the sun; but as great accuracy in the determination of the angles was not needed, it was found sufficient to readjust it every few minutes. Another advantage of this arrangement was, that the line of junction, being turned parallel to the axis, would always lie in the plane passing through the sun, and hence be parallel to the plane of polarization. Table XI. gives the result of five series of observations made in this way: —

TABLE XI.

Sky Polarization. Points equidistant from Sun.

12. July 15.

Sun's Dist. 90°, Alt. 5°.

M. D.	Polar.
75	78.6
60	74.3
45	79.8
30	77.0
0	77.2
30	74.8
45	75.2
60	76.8
75	76.8
Mean	76.7

13. July 20.

Sun's Dist. 60°, Alt. 20°.

M. D.	Polar.
0	44.1
30	41.3
60	40.7
—90	42.9
—60	45.7
—30	38.5
Mean	42.9

14. July 30.

Sun's Dist. 90°, Alt. 48°.

M. D.	Polar.
0	61.8
—30	69.0
—75	69.7
75	60.5
60	60.2
0	61.6
—55	68.7
—60	71.7
Mean	65.4

Sun's Dist. 60°, Alt. 45°.

M. D.	Polar.
0	45.7
30	42.6
60	41.3
90	39.4
110	36.2
—30	49.1
—60	38.7
—90	39.7
—110	41.3
0	42.9
Mean	41.7

Sun's Dist. 120°, Alt. 42°.

M. D.	Polar.
0	45.7
30	39.1
Mean	42.4

Sun's Dist. 30°, Alt. 40°.

M. D.	Polar.
0	13.6
60	5.2
90	7.3
120	8.5
180	5.9
—120	19.1
—90	15.3
—60	16.0
Mean	10.7

15. Sept. 12.

Sun's Dist. 90°, Alt. 40°.

M. D.	Polar.
0	66.9
30	67.9
60	66.4
75	61.6
0	66.4
30	68.2
60	65.1
75	65.6
90	54.8
0	65.6
Mean	60.4

Sun's Dist. 120°, Alt. 41°.

M. D.	Polar.
0	42.9
30	44.3
45	44.5
55	41.6
0	40.5
—30	41.3
—45	37.5
—55	35.8
0	38 1
Mean	40.9

Sun's Dist. 60°, Alt. 43°.

M. D.	Polar.
0	30.9
30	35.5
60	37.5
90	33.9
120	33.2
—30	35.8
—60	31.9
—90	32.6
—120	33.4
0	31.9
Mean	34.2

16. Sept. 12.

Sun's Dist. 90°, Alt. —5°.

M. D.	Polar.
0	77.9
—30	79.4
—60	79.0
—75	77.8
0	75.0
30	75.7
Mean	77.5

The first column gives in each case the meridian distance, the second the mean of the four positions of equality of the Nicol's prism, and the third the corresponding polarization. All these observations point to one very remarkable result; namely, that the polarization is the same for a given solar distance for any meridian distance; in other words, that the polarization is the same for all points equally distant from the sun. The variations in the observations are to be ascribed partly to errors of observation and partly to real irregularities in the atmosphere, as it is evident that they follow no regular law. The means therefore give us the true polarization with much greater accuracy. They are represented in Fig. 5 by small crosses. The next thing is to determine the law which connects the polarization with the solar distance in all these observations. A drawing was made like Fig. 5 enlarged, and a fine copper wire laid on it, and bent into such a shape that it should coincide as nearly as possible with all the observations. The ordinates for every 10° were then read off, giving the results entered in column 2 of Table XII.

TABLE XII.

Theoretical Formula for Sky Polarization.

S. D.	Obs.	Theor.	Differ.
0	0.0	0.0	0.0
10	1.0	1.0	0.0
20	3.5	4.2	+ 0.7
30	9.0	10.0	+ 1.0
40	17.5	18.2	+ 0.7
50	28.5	29.0	+ 0.5
60	41.0	42.0	+ 1.0
70	56.0	55.4	— 0.6
80	67.0	66.1	— 0.9
90	72.0	70.0	— 2.0
100	68.0	66.1	— 1.9
110	58.0	55.4	— 2.6
120	44.0	42.0	— 2.0
130	30.0	29.0	— 1.0
140	18.0	18.2	+ 0.2
150	8.5	10.0	+ 1.5
160	3.0	4.2	+ 1.2
170	1.0	1.0	0.0
180	0.0	0.0	0.0

A simple explanation of the polarization of the sky is to assume that it consists of molecules of air or aqueous vapor, which reflect the light specularly, and whose index of refraction differs only by a very minute amount from that of the medium in which they float. The theoretical

polarization would then be at once given by Table II., making i equal to one-half the solar distance. The curve thus obtained is given in Fig. 5, at A. The polarization according to this should be complete at 90° from the sun, while in reality it is only about 70 per cent. If, however, we multiply the ordinates of curve A by this fraction, we obtain curve B, which agrees almost precisely with the curve given in column 2 of Table XII. Its ordinates are given in column 3, and the differences in column 4. From the latter it will be seen that the empirical curve gives results somewhat too great for solar distances less than 60°, and too small for greater distances; but the deviation is so small, compared with the accidental errors, that we are scarcely justified in drawing any conclusions from them. The agreement of all the observations in the neighborhood of 120° from the sun is remarkable, and not easily explained. The observations of series 10 for distances less than 110° give results decidedly below that given by theory. A possible explanation is the reflection of the sun on the sea to the east of Boston, a source of error not present in the earlier observations which were made inland. It will be noticed that no account is here taken of the points of no polarization, or neutral points of the sky; but the polarization is very slight for some distance from them, and hence is not easily measured. They must be regarded as due to some secondary disturbing cause, as refracted light, which alters the general polarization of the sky but little.

When the polarimeter is directed towards a polished colored plane surface, the two images assume different tints. One, which contains the light polarized in the plane of incidence, or B, is composed mainly of the light reflected specularly, and is therefore white like the source of light. The image A contains but little of the light reflected specularly, consisting principally of the rays emitted by the body, and hence partaking of its color. The idea at once suggested itself, that testing the light of the sky in this way might give a clue to the cause of its color. The experiment was tried several times, with negative results, the two images appearing of precisely the same blue tint. But on the evening of July 15th, near sunset, when measuring the polarization of a point near the northern horizon, where the blue color was comparatively pale, a marked difference in the two images was observable. The image B was found to be of a yellowish brown, A of a grayish blue or violet tint. This observation has since been frequently repeated, and can, in fact, be made almost any clear evening near sunset. Evidently we may conclude from these colors that the true color of the sky particles is blue, a view quite in accordance with

the observations of Prof. Cooke with the spectroscope, and of Prof. Tyndall on aqueous vapor in a state of formation.

Observations were next made to test the results found above, for the light reflected and transmitted by several parallel surfaces of glass. To check the results, which are given in Table XIII., two, and in some cases three, independent methods were employed. For convenience of reference, the series are numbered, as in the observations on sky polarization. The general method employed to measure the polarization of the reflected ray was to lay one or more sheets of glass on a piece of black velvet, and render them horizontal with a spirit-level. The polarimeter was then mounted a short distance from them, carefully levelled and then turned down, so that the light should be reflected from their surfaces. Its angle of depression would then equal the complement of the angle of incidence. The line of junction of the two images was then rendered vertical, and the polarization measured in the usual way. The polarization of the sky, if clear, would introduce a large error into the results, and care was therefore taken to make these observations only on cloudy days. Although it is commonly stated that no traces of polarization can be detected in the heavens when completely covered with clouds, yet it was found to be slightly polarized in a vertical plane at such times, the effect being most marked near the horizon, and probably due to reflection from terrestrial objects. To obtain a single surface of glass, a piece was blackened on one side in the flame of a candle, in the expectation that the oil in the lamp-black, having nearly the same index of refraction as the surface to which it adhered, would prevent all specular reflection from it. But the results obtained did not agree with those computed for a single surface, and a close examination showed that double reflections were given of objects in front, as with a common plate of glass; in fact, that the lamp-black acted merely like the velvet in the other cases. The two series, Nos. 20 *a* and 21 *a*, are therefore placed with the observations on two surfaces, with which they agree very well. A piece of colored glass was next used, which gave the results in the column headed 17 *a*. Series 22 *a*, 27 *a*, 35 *a*, and 36 *a* were obtained in the same manner, using 1, 4, and 10 pieces of plate glass, laid on one another so as to form a pile.

The other measurements of the polarization of the reflected beam were obtained by quite a different method. A large Babinet's goniometer, or optical circle, was employed, the slit being removed and replaced by a Nicol's prism, which was free to turn around its axis, the angle of rotation being measured by a graduated circle and index. In the eye-piece of the observing telescope, a Nicol's prism was placed, and

TABLE XIII.

Observed Polarization of 1, 2, 8, and 20 Surfaces of Glass.

ONE SURFACE.

Reflected Beam.				
i	17 *a.*	18 *b.*	19 *b.*	Theor.
0°	—	—	—	0.0
10	—	—	—	4.1
20	17.0	17.4	17.0	16.4
30	38.6	38.7	39.5	37.8
40	72.7	68.4	69.2	66.7
45	79.9	83.5	85.0	81.2
50	93.6	94.5	94.8	92.9
55	97.2	99.9	99.9	99.8
60	97.6	97.7	97.8	98.8
65	87.8	88.8	88.0	91.2
70	77.5	78.8	71.7	77.7
75	58.5	58.5	52.8	61.8
80	41.0	38.7	34.9	41.0
82	—	29.6	27.2	32.8
84	—	23.5	19.9	24.7
85	20.1	18.4	18.9	20.6
86	—	15.6	18.7	16.5
87	—	12.9	9.2	12.4
88	—	5.6	4.9	8.2
89	—	—	—	4.1

TWO SURFACES, ONE PLATE.

	Reflected Beam.					Refracted Beam.			
i	20 *a.*	21 *a.*	22 *a.*	23 *b.*	Th.	24 *a.*	25 *b.*	26 *b.*	Th.
0°	—	—	2.8	0.0	0.0	0.0	—0.7	1.0	0.0
10	2.5	4.5	—	—	4.1	—	2.4	1.4	0.4
20	19.7	22.1	17.0	14.9	16.8	1.4	0.0	—	1.6
30	36.0	42.8	34.9	37.8	36.4	4.9	4.9	—	3.6
40	62.5	62.9	62.9	65.6	64.0	7.8	7.7	—	7.2
45	75.1	79.4	80.8	79.9	80.1	—	9.8	—	9.4
50	87.9	88.1	92.4	98.4	95.6	11.8	11.5	—	12.5
55	95.7	94.4	98.0	99.6	99.8	14.8	14.6	—	15.6
60	98.6	98.2	97.6	98.0	98.8	15.6	19.1	17.4	19.2
65	87.1	85.9	89.3	87.5	87.7	20.1	23.2	23.8	23.2
70	69.2	71.9	71.0	71.2	72.6	26.2	27.2	26.2	28.4
75	53.9	52.4	56.2	51.5	52.2	34.2	30.9	32.2	33.2
80	30.9	37.1	33.2	35.5	30.7	34.9	36.8	39.7	37.2
82	—	—	—	22.8	22.7	31.9	39.7	41.3	38.6
84	—	—	—	20.8	15.7	—	40.3	45.7	39.6
85	16.0	19.8	18.4	21.1	12.6	39.4	41.3	48.5	40.0
86	—	—	—	—	9.8	—	46.9	50.3	40.4
87	—	—	—	—	7.0	—	49.3	56.2	40.8
88	—	—	—	—	4.4	—	49.3	56.8	41.1
89	—	—	—	4.2	2.0	—	55.8	51.2	41.2

TABLE XIII., — *continued.*

Observed Polarization of 1, 2, 8, and 20 Surfaces of Glass.

EIGHT SURFACES, FOUR PLATES.

	Reflected Beam.			Refracted Beam.						
i	27 *a.*	28 *b.*	Th.	29 *a.*	30 *b.*	31 *c.*	32 *c.*	33 *c.*	36 *c.*	Th.
0°	—	0.7	0.0	0.7	—0.8	0.0	1.7	0.5	1.2	0.0
10	4.9	—	8.4	1.4	0.3	—	—	—	—	1.2
20	16.0	14.8	18.1	6.6	5.2	4.2	9.8	—	—	5.1
30	81.9	80.6	29.2	12.9	12.5	12.9	—	—	—	11.4
40	62.9	56.5	56.4	19.8	23.5	28.8	28.5	—	—	21.8
45	75.7	73.4	73.8	27.9	81.2	—	—	—	—	28.1
50	88.1	88.8	88.7	38.5	87.5	87.1	86.5	—	—	35.1
55	96.8	99.0	98.8	41.8	48.5	45.7	—	—	—	42.0
60	92.8	96.5	95.0	50.0	51.8	49.7	48.4	52.4	58.0	48.9
65	75.5	74.8	81.0	55.6	58.8	58.5	—	57.5	59.9	54.1
70	52.1	44.8	51.9	61.6	66.4	64.8	64.0	68.5	62.4	56.8
75	83.2	20.8	27.8	67.7	71.4	64.0	66.9	65.6	66.1	55.8
80	19.8	8.0	12.8	64.8	74.5	62.9	77.5	72.7	70.5	52.6
82	—	—	8.2	66.4	81.5	—	—	79.0	75.9	50.5
84	—	—	5.2	64.5	91.8	—	—	—	—	48.6
85	11.8	5.9	8.8	61.6	89.7	—	—	—	—	47.5
86	—	—	2.6	54.2	—	—	—	—	—	46.2

TWENTY SURFACES, TEN PLATES.

	Reflected Beam.				Refracted Beam.				
i	35 *a.*	36 *a.*	37 *b.*	Th.	38 *a.*	39 *b.*	40 *b.*	41 *c.*	Th.
0°	—	—	1.4	0.0	1.7	0.2	0.0	0.7	0.0
10	—3.8	5.0	—	2.1	5.6	0.7	2.8	—2.1	2.1
20	8.7	16.8	8.0	8.5	10.8	10.1	18.6	9.8	8.8
30	29.2	25.2	16.0	21.2	25.2	20.8	28.6	22.1	19.7
40	52.4	55.0	36.5	42.4	39.4	45.1	46.8	44.8	36.7
45	70.2	68.7	51.8	55.9	53.8	56.9	62.7	54.0	46.6
50	85.8	83.8	78.1	79.5	63.7	71.9	74.8	63.7	56.4
55	95.8	96.2	97.4	97.5	70.5	82.9	85.8	76.6	64.5
60	90.6	88.5	86.1	94.5	78.4	94.8	91.6	82.1	71.0
65	62.7	65.8	67.5	64.7	81.8	97.7	93.8	85.9	72.2
70	41.8	87.5	81.9	83.0	81.1	—	97.0	91.2	70.0
75	22.5	88.9	18.9	11.8	76.6	99.1	—	94.7	64.6
80	19.8	17.0	11.8	5.6	71.9	79.6	—	85.2	57.1
85	18.0	8.6	9.4	1.6	58.2	—	—	—	49.8

in front of it quartz wedges giving lines, which were bright or dark centred, according as the transmitted ray was polarized vertically or horizontally. On looking through the telescope, the field was seen to be traversed with lines, which disappeared only when the Nicol in the collimator was inclined 45° with the vertical. At any other angle, *a*,

the vertical and horizontal components, were $\cos^2 a$ and $\sin^2 a$, and hence were equivalent to a beam polarized vertically by an amount $\cos 2a$. If now any object was inserted between the two telescopes polarizing the light horizontally p, the bands would disappear only when $p = \cos 2a$. Measuring the four positions of disappearance, and taking their mean, gave an accurate measure of the polarization by Table IX., using it as with the polarimeter described above. Another way of expressing the effect of this instrument is to say that the bands disappear when the Nicol is so turned that the plane of polarization shall be brought by the object under examination to an angle of 45°. The method of measuring the polarization of the reflected ray is now obvious. The pieces of glass are placed vertically on the centre plate between the two telescopes, the latter set at an angle of $2i$, and the glass turned until the light is reflected from its surface, so as to render the field bright. The Nicol is then turned until the bands disappear, and its position recorded. The angle between the telescopes is then altered so as to make i successively 20°, 30°, 40°, &c., and the observation repeated. Various adjustments must be made to eliminate constant errors, but they need not be detailed here. Series 18 *b* consists of observations thus made on a glass prism having an index of refraction of 1.517; series 19 *b* was made with colored glass; series 23 *b* was made with one sheet of plate-glass; and series 28 *b* and 37 *b* with 4 and 10 microscope slides respectively. The latter were used, as the thickness of the plate-glass was such that, when a number of plates were placed between the telescopes, a portion of the internal reflection would be lost.

To measure the polarization by refraction, two similar methods were employed. The plates were placed vertically over the centre of a graduated circle, and a piece of ground-glass was viewed through them by the polarimeter. The plates were then set at various angles, and the polarization measured in each case. All these observations were made in cloudy weather, to eliminate the effect of sky polarization. Series 24 *a*, 29 *a*, and 38 *a* were obtained in this manner. Other observations were made with the optical circle, placing the telescopes opposite each other, and recording the angles of the Nicol for various positions of the plates. The results are shown in columns 25 *b*, 26 *b*, 30 *b*, 39 *b*, and 40 *b*. Still a third method was employed, already described in connection with the Arago's polarimeter. Four series — columns 31 *c*, 32 *c*, 33 *c*, and 34 *c* — were thus measured with four slips of glass for microscopic slides, and one series, 41 *c*, with ten pieces of plate-glass.

To show more clearly which method of measurement was employed

in each series, the letter *a* is attached to all the columns measured with the polarimeter, *b* to those measured on the optical circle with Babinet's wedges, and *c* to those in which the point of disappearance of Savart's bands was found.

It will be noticed that no observations are given of the polarization of a beam transmitted by one surface of glass. There seemed to be no easy method of measuring this quantity. It might be done by making a series of prisms of such angles that when the light was incident on one face at 10°, 20°, 30°, &c., the refracted ray would strike normally on the second face. The effect of the latter would then be nothing, so that the polarization would in this case be entirely due to the first surface.

We proceed now to discuss the results given in Table XIII. Examining the observations on a single surface of glass, we see that their concordance is much greater than in the observations of sky polarization, although two quite distinct methods were employed. The column headed "Theor." gives the theoretical polarization as given in Table VI. The observed polarization is somewhat too great for angles less than 57°, and too small for greater angles. The difference may be explained by the fact that the index of refraction was somewhat less than 1.55, hence the angle of total polarization less than 57°. The same results are shown in Fig. 6, in which abscissas represent angles of incidence, and ordinates polarization. In the case of the light reflected by two surfaces, Fig. 7, the agreement is also very close. The same may be said for the refracted beam for angles below 80°. It is difficult to observe the polarization at greater angles, as the light then passes so obliquely through the glass. There seems, however, to be a decided excess of the observed over the theoretical polarization. Two series only, of observations on the light reflected by four plates of glass, Fig. 8, were taken, as they seem to agree sufficiently well with each other, and with theory. The case of the light transmitted by four plates of glass has special importance from its application to the polarimeter of Arago. For although, of course, any other number of plates might be used, yet this number, since the eclipse of 1871, seems to have been more frequently employed. Six concordant series are given, obtained by three distinct methods, and all agree in showing a marked divergence from theory for angles greater than 60°, the observed being greater than the computed polarization.

The observations on twenty surfaces, as might be expected, present still greater discrepancies. As regards the reflected ray, Fig. 9, series 37 *b* agrees pretty well with theory, but gives a much less result than

either 35 *a* or 36 *a*. Both of the latter were taken by the same method, and agree pretty well together, but differ from theory at 45° by 15 per cent. The variations of the refracted beam, Fig. 10, are still greater. As before, the observations taken by the same method as 39 *b* and 40 *b* agree, but 41 *c*, taken with the Savart, gives smaller results; series 38 *a*, with the polarimeter, still less; and theory, least of all. The errors most likely to occur, which would be common to all the observations on the refracted beams, are, first, stray light, or light entering the instrument without passing through the glass; secondly, light passing through the glass endwise, which might be recognized by its deep green color; and, thirdly, light reflected from the front surfaces of the plates. But all these errors would tend to diminish, instead of increase, the polarization; and hence, if eliminated, the divergence from theory would be still greater. Probably the true explanation is that internal reflection does not take place as completely as theory assumes, partly owing to the imperfect transparency of the medium, and partly to the dust and other impurities on the surface. Comparing the results with Table VII., which shows the effect when there is no internal reflection, we see that it makes but little difference for the reflected rays, the polarization being the same for three values of i, namely, 0°, 57°, and 90°. For the refracted ray, on the other hand, the variations are very great, amounting in the case of twenty surfaces, at 90° incidence, to over 50 per cent. We also see from Tables VI. and VII. that a partial absence of the internal reflection would account for all the results obtained, while neglecting it entirely, would cause a still greater divergence between theory and observation.

On account of the thickness of the bundle of ten plates of glass, a portion of the secondary reflection would be thrown a considerable distance to one side, especially when i is large, so that it might fall quite outside of the instrument, or even be cut off by the ends of the plates. This effect would be least marked with the polarimeter, next with the Savart, and most of all with the optical circle, on account of the small aperture of the telescope. But this is just the order in which the observations stand, all of them falling between the two theoretical curves. These observations with Tables VI. and VII. also show the effect to be expected from a bundle of plates when used to polarize light by refraction. If ten plates are employed, set, as is usual, at 57°, the polarization would be only 67.2 per cent if internal reflection takes place, but would be 95.2 if this is in any way excluded. We may, in passing, point out that an advantage might be expected in such a polariscope from an increase in the angle of incidence, the increased

polarization probably more than making up for the loss of light and distortion induced by the increased obliquity of the incident rays.

The want of perfect transparency of the glass would also tend to increase the polarization by enfeebling the secondary reflection, and dirt or grease on the surface of the glass would produce the same effect. With eight surfaces, these disturbing causes are much less marked, except for large angles of incidence, and hence the agreement with theory much better. Beyond 60°, however, it becomes perceptible, producing the increased polarization noticed above. Even with a single plate of glass, this disturbing cause becomes perceptible, which probably accounts for the divergence for angles greater than 80°.

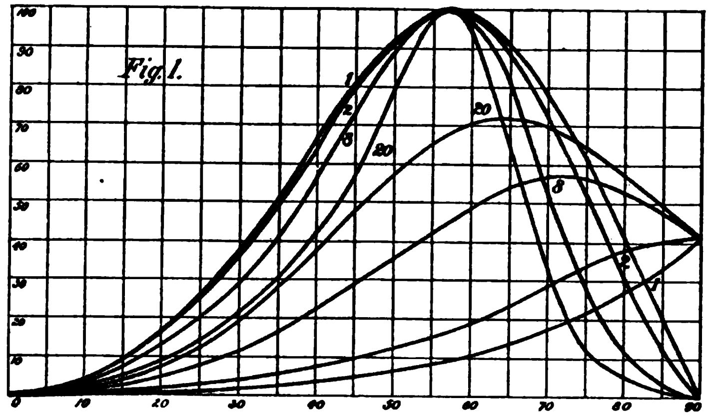


Fig. 1.
1
2
8
20
20
8
2
1
100
90
80
70
60
50
40
30
20
10
0
10
20
30
40
50
60
70
80
90

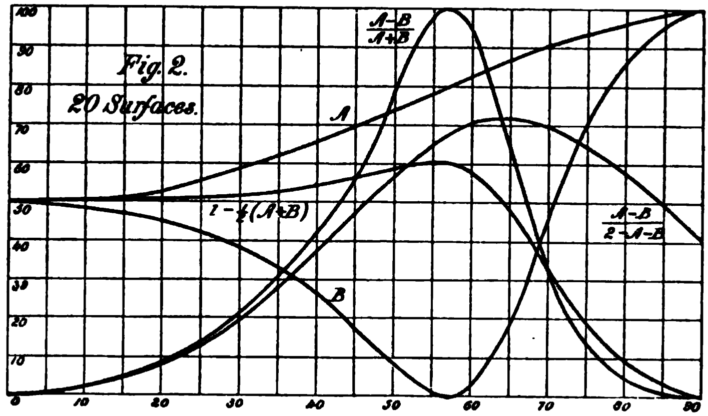


Fig. 2.
20 Surfaces.
$\frac{A-B}{A+B}$
A
$1-\frac{1}{2}(A+B)$
$\frac{A-B}{2-A-B}$
B
100
90
80
70
60
50
40
30
20
10
0
10
20
30
40
50
60
70
80
90

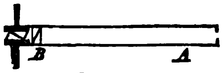

B
A

Fig. 3.

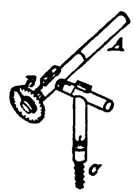

A
B
C

Fig. 4.

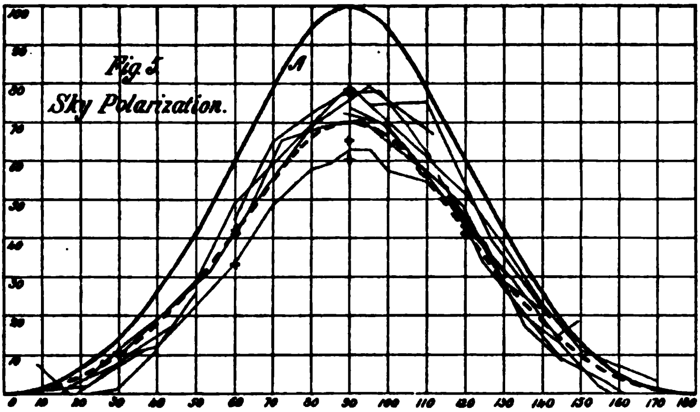


Fig. 5.
Sky Polarization.
A
0 10 20 30 40 50 60 70 80 90 100 110 120 130 140 150 160 170 180

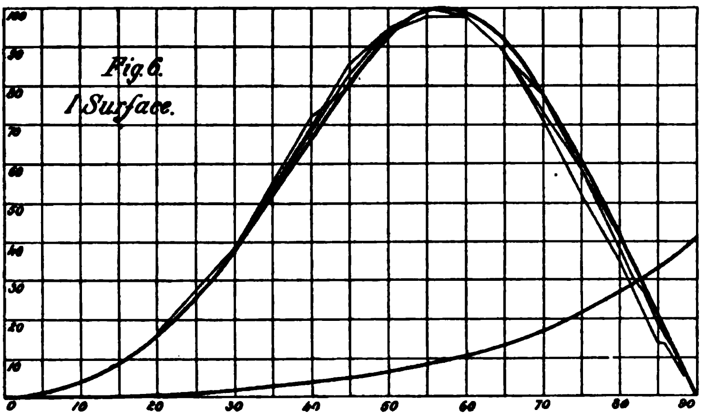


Fig. 6.
1 Surface.
0 10 20 30 40 50 60 70 80 90

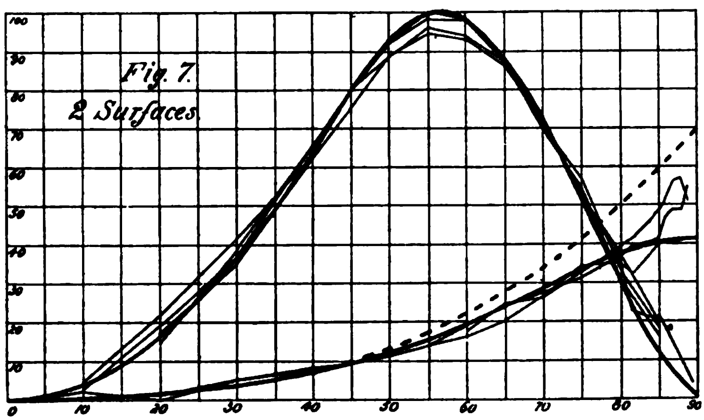


Fig. 7.
2 Surfaces.
0 10 20 30 40 50 60 70 80 90

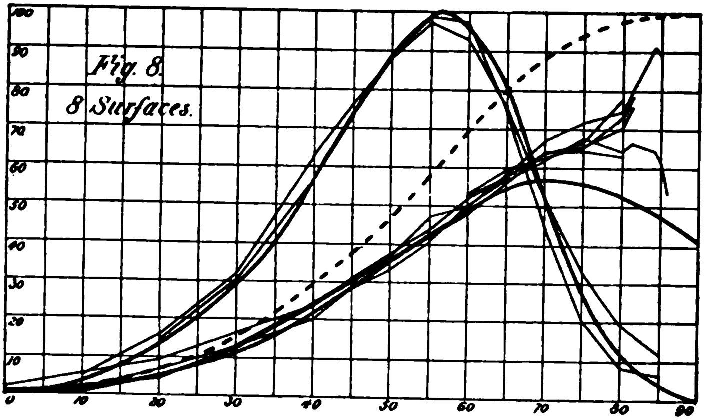


Fig. 8.
8 Surfaces.

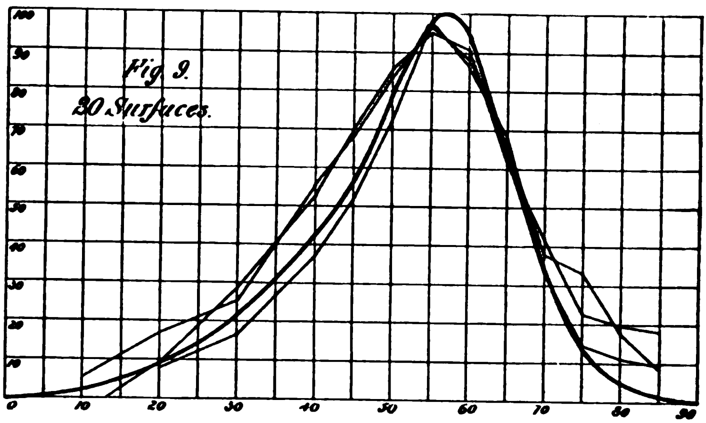


Fig. 9.
20 Surfaces.

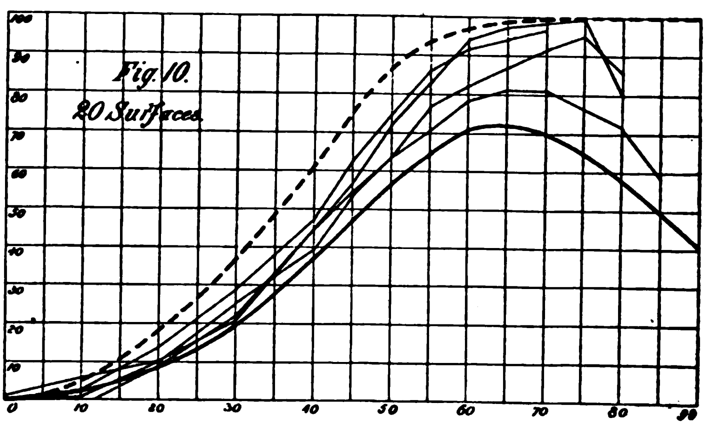


Fig. 10.
20 Surfaces.

II.

REPORT OF COMMITTEE APPOINTED TO MEMORIALIZE THE LEGISLATURE OF THE STATE OF MASSACHUSETTS ON THE SUBJECT OF EXPERT TESTIMONY.

Read, Oct. 14, 1873.

YOUR Committee, who had in charge the duty of presenting to the Legislature the importance of some legislative action upon the subject of employing the testimony of the class of witnesses known as experts in the trials of causes in courts, respectfully report.

The Chairman received a notice from "the Committee on the Judiciary on the part of the House" that they would "give a hearing to parties interested in an order relative to medical testimony in criminal cases," on the 28th day of March last. And although the order, in its terms, was more limited in its scope than the subject with which your Committee deemed themselves to be charged, the Chairman attended at the time appointed, and endeavored to present what was believed to be the views of the Academy upon the general subject of expert testimony, with the reasons why, in their judgment, some efficient measures of reform in respect to this was important and desirable.

These views were listened to by the Committee with great courtesy and apparent attention. To aid them in understanding the purposes at which the Academy aimed, as well as to suggest some of the means by which, in their judgment, these purposes might be attained, the draft of a bill or legislative act was laid before them, which had been submitted for consideration to able and discreet jurists, and others of acknowledged sagacity, as well as several members of the Academy, and had been by them approved. Of this the Committee were fully apprised; as well as of the fact that, in what they were doing upon this subject, the Academy were acting in harmony with three other associations of gentlemen interested in science, — viz., The Suffolk District Medical Society, The Boston Society for Medical Observation, and The Boston Society for Medical Science, — and that the attention of these Associations had been specially called to the subject of expert testimony, by more or less of their members having been required to give such testimony in matters of scientific inquiry and investigation.

It was urged, too, before the Committee, that it was obviously ungenerous, as well as unjust, at the same time that it tended to bring the administration of justice into contempt, to compel honest and honorable experts, who had made themselves masters of any science by study, observation, and experience, to put themselves in conflict in open court upon, so far as the public saw, terms of equality with pretenders, who were willing to lend themselves, and the science to which they pretended, for hire, to promote the views or interests of their employers. And this, too, when the comparative claims of the two to confidence and respect were to be passed upon and determined by jurors drawn from the various walks and pursuits of life, untrained and uninformed in the matters upon which they are called to judge. Instances were cited and enumerated from both English and American courts, where juries have been subjected to such a discrimination, while the lives of persons upon trial depended upon the hap-hazard result to which they might come in trying to distinguish between what was true and false in science.

Whether and how far these suggestions were deemed worthy of thought or attention, your Committee have no means of judging. The first and only communication with which they have been favored by the Committee of the Judiciary was a brief note, bearing date May 24th, which simply announced that "the Committee do not see their way clear to reporting favorably upon the accompanying bill." This refers to the original draft of the bill, which had been left with them, and accompanied the note. The note contained no reasons for the result at which the Committee had arrived, nor how far, if at all, the scheme found favor with them.

If the bill was objectionable in any of its terms or details, it is much to be regretted that it did not occur to the Committee that these might easily be modified or wholly changed, inasmuch as the bill, as offered, was merely by the way of suggestion, and might, without objection, have been wholly changed in its form, if it could any better express the views of the Committee.

If the brevity of the session, or the period of two months during which the Committee held the matter in their hands, was inadequate to the forming of a satisfactory conclusion upon the subject submitted to them, it ought to be regarded as a public misfortune. If, on the contrary, it was the deliberate judgment of that Committee that the course of justice is better served, and the honor of our courts more effectually advanced, by such exhibitions of trumped-up testimony and pretended skill and science as have, at times, signalized what are called

judicial trials, than would be likely to be done by any proposed reform which they were asked to inaugurate, it might perhaps lead the Academy to believe that the public mind is not yet sufficiently awakened to the importance of providing a remedy for an existing crying evil, and thereby stimulate them to a still further effort to convince others of the necessity of some action in the premises.

As things stand, they ought not to let the matter rest in silence. The mischief at which they aim is becoming more glaring every year, and public attention in various quarters is being called to it in a significant manner, both in England and our own country. Nor is it wise to suffer this interest to subside, until some remedy has been devised, or is found impracticable.

Had the Committee on the Judiciary seen fit to favor the Academy with their views upon the matter, it might have aided its members in forming a judgment as to the course they ought to pursue. In the absence of these, however, your Committee have thought proper to accompany their report by the draft of the bill before mentioned, that, if the Academy should hereafter see fit to take any further action upon the matter, it might serve, by way of suggestion, to point out the objects which are aimed at by them.

In conclusion, your Committee cannot but express a hope that the attempt to interest the Legislature in the subject now under consideration, which has been twice repeated, will be renewed and reiterated till associations as numerous and respectable as those who have here undertaken to speak in behalf of the cause of science and truth, in which they have a personal but no pecuniary interest, may hope to obtain a response from those to whom their appeal is addressed, which will sustain them in their endeavors to accomplish a public benefit, or show wherein they are mistaken in what the public needs. Nor are they willing to doubt that, in due time, a community so ready as ours is to boast of its schools, its colleges, and its institutes of science, will devise some way by which, in the investigations of scientific truths in judicial trials, the value, together with the honor and dignity, of science, as well as truth, may be vindicated and sustained.

An Act concerning the Testimony of Experts.

Be it enacted, &c., as follows:

Section 1. Whenever the District Attorney of any district in the Commonwealth, or the Attorney-General, shall be informed of the death of any person in such district, and that there is reasonable cause to suspect that the same is a case of homicide, and he shall be of opinion that

it is proper to cause a scientific investigation to be made into the causes and circumstances of such death, it shall be his duty forthwith to apply to one or more of the justices of the Supreme Judicial Court to appoint one or more discreet and experienced experts, who shall be deemed to be competent to conduct such investigation, and to form a conclusion upon the questions involved therein. And said justice or justices shall thereupon select and appoint such expert or experts accordingly. The compensation which shall be adjudged reasonable by the Court for the services of such experts, together with the costs of making such investigation, shall be allowed and paid in the same manner as other costs in criminal proceedings.

SECTION 2. If, in the trial of any issue in any of the courts of the Commonwealth, the presiding judge shall be of opinion that the testimony of one or more expert witnesses, versed in matters of skill or science, a knowledge of which is material to a satisfactory determination of such issue, may be useful or important in such trial, it shall be competent for such judge, upon the application of either party to such issue, and after a hearing of such parties, if they shall desire it, to select and appoint one or more such expert witnesses, and to require their attendance to give testimony in such trial. And the witnesses so selected and appointed shall attend and be examined in the same manner as other and ordinary witnesses, when testifying in the trial of such issues. The court shall allow such witnesses, for their services and attendance in such trial, such sum as may be adjudged reasonable, to be advanced and paid as is provided in respect to the fees of ordinary witnesses. And the sums so advanced and paid by either party, if prevailing in the suit, shall be charged by and allowed to him as a part of his costs, as in the case of other witnesses, unless the court for good cause shall order otherwise.

SECTION 3. Neither party shall be entitled to claim a delay or continuance of any trial, for the purpose of calling in the testimony of expert witnesses, unless the court shall be satisfied that there has been no unreasonable delay in making application for such appointment.

III.

THE VERMICULITES:

THEIR CRYSTALLOGRAPHIC AND CHEMICAL RELATIONS TO THE MICAS;

TOGETHER WITH A DISCUSSION OF THE CAUSE OF THE VARIATION OF THE OPTICAL ANGLE IN THESE MINERALS.

BY JOSIAH P. COOKE, JR.,
Erving Professor of Chemistry and Mineralogy in Harvard College.

Read, Dec. 9, 1873.

Introduction. — In the American Journal of Science (VII. 55, 1824), T. H. Webb described a mineral from Millbury, near Worcester, Mass., which has since been a mineralogical curiosity on account of its singular reaction when heated. The mineral consists of "small foliated scales distributed through a steatitic base." "When heated, it exfoliates prodigiously, the scales opening out into long worm-like threads made up of the separate foliæ. Exfoliation commences at 500° to 600° Fahr., and takes place with so much force as often to break the test-tube in which the mineral may be confined. Before the blowpipe it fuses at 3.5 to a grayish-black glass." It was named by Webb, as he says, "from the Latin *vermiculor*, 'I breed worms.'" The hardness of the mineral is 1–2, the specific gravity 2.756, the lustre talcose, and the color grayish, somewhat brownish. It was analyzed by Crossley, who "separated with great care from the base the scaly mineral, which is the true vermiculite," and his results were as follows:—

			Oxygen Ratio.				*Oxygen Ratio.*	
	1.		True	App.	2		True	App.
Silica . . .	35.74	19.06	19.06	11	35.74	19.06	19.06	2
Alumina . .	16.42	7.65	7.65	4	16.42	7.65		
Ferric Oxide .					11.13	3.34	10.99	1
Ferrous Oxide	10.02	2.23						
Magnesia . .	27.44	10.98	13.21	7	27.44	10.98	10.98	1
Water . . .	10.30	9.16	9.16	5	10.30	9.16	9.16	1
	99.92				101.03			

The results of analysis in column 1, and the portions of the description of the mineral in quotation-marks, above, have been taken from "Dana's System of Mineralogy," fifth edition, page 493; and the atomic ratio which is there deduced is,

$$\overset{\mathrm{IV}}{Si} : \overset{\mathrm{VI}}{\mathbf{R}} : \overset{\mathrm{II}}{R} : \overset{\mathrm{II}}{\mathrm{H}} = 11 : 4 : 7 : 5.$$

In this analysis, however, Crossley could not have determined the state of the iron, which, in the specimen I have examined, is almost wholly in the ferric condition. If now we assume that the whole of the iron belongs with the sesquioxide radicals, the analysis would appear as in column 2, and the atomic ratio is then seen to be 2 : 1 : 1 : 1, which is undoubtedly the correct result.

In the year 1851, Mr. W. W. Jefferis, of West Chester, Pa., discovered at the ripidolite locality near that town a peculiar micaceous mineral which exfoliates like the Millbury vermiculite, but which, instead of occurring in small foliæ, is found in large hexagonal plates. This mineral was analyzed by Professor Brush; and although at first referred by him, "with a query," to vermiculite (Am. Jour. Sci., II. xxxi. 369, 1861), was subsequently described as a new species (Am. Jour. Sci., II. xli. 248, 1866), and named Jefferisite.

Several years later, Mr. John Hall, now of Philadelphia, sent to me for examination some rough six-sided prisms of a micaceous mineral, which he had discovered at East Nottingham, in Chester County, Pa. This mineral also exfoliates when heated. It is a new species, and I have named it, after the discoverer, Hallite.

A year since I received from Colonel C. W. Jenks, in connection with other minerals from his corundum mine on the Culsagee River, in Macon County, N. C., a specimen of still another micaceous mineral having the same remarkable pyrognostic properties. It proved to be the best defined of any of this class of minerals which I had examined, and I shall designate it as Culsageeite.

Besides the above, there have been found several other micaceous minerals whose pyrognostic and crystallographic characters indicate that they belong to the same family, but which have not yet been investigated.

The remarkable exfoliation and great apparent increase of volume which the class of mineral under consideration undergo when heated are analogous to the well-known phenomena presented in the dehydration of alum, borax, and other crystalline salts, when heated in a similar way; and it will be one object of this paper to show that the effect is due to the same cause, — namely, to the escaping of what we call water

of crystallization. I also expect to show that the several minerals referred to above are members of a family of hydrous silicates closely allied and parallel to the well-known family of anhydrous silicates called the micas, and that their molecules differ from those of the magnesian micas chiefly in containing a definite number of molecules of water; that is, water of crystallization. I shall call this family of minerals "the vermiculites," using the original name, as "mica" is now employed, to designate a class; and I shall call the three species (or varieties?) of this family Jefferisite, Culsageeite, and Hallite; which correspond, as I expect to show, to the two varieties of Biotite and to Phlogopite respectively. It will appear that the original vermiculite has the same composition as the variety from the Culsagee mine. Finally, attention will also be asked to some unexpected discoveries to which the optical examination of these minerals has led.

Water of Crystallization and Water of Constitution.—In the salts of the stronger acids, the distinction between water of constitution (basic water, as it is sometimes called) and water of crystallization is, as a rule, well marked. Water of crystallization generally escapes at a comparatively low temperature, and the loss is attended with a complete disintegration of the crystals, which usually fall to powder. Water of constitution is held more firmly, and the salt must be heated to a much higher temperature before it is expelled. Moreover, athough the loss of basic water may greatly alter the external aspect of the body, yet there is not the same complete breaking up of the structure as before. To illustrate these points, it is only necessary to refer to the well-known reactions of the common rhombic sodic phosphate when heated.

It is generally believed that the water of crystallization exists as such in the salt, the molecules of water forming a part of the structure of the crystals; and the facts to be presented in this paper tend to support this view. But our modern theories assume that the so-called water of constitution, which may be also driven off when the salt is sufficiently heated, is formed under the influence of the heat from the atoms of hydroxyl $H\text{-}O\text{-}$, which are united to the acid radical of the compound. But in every simple salt, whatever may be our theories in regard to the mode of combination, the weight of the water of constitution, as well as that of the water of crystallization, must bear to the weight of the salt a definite proportion, which can easily be calculated from the symbol; and the ratio between the amount of hydrogen and the amounts of the other radicals must be that of the atomic weights of these radicals or of their multiples. In any given class of salts,

moreover, in which the ratio between the atomicity of the basic and acid radicals has a constant value, all hydrogen, which represents water of constitution, will supplement the other basic radicals, and added to them will complete the relative amount of basic radical which the given class of salts require; while the hydrogen, which represents water of crystallization, will be in excess of that amount.

In mineral silicates these relations are complicated by the phenomena of isomorphous replacements, and, although there may be some question in regard to the replacing capacity of hydrogen, we cannot expect the same constancy in the amount of water of constitution, which these minerals contain, as in the case of simple salts. The amount of water of crystallization, however, must be as invariable in one case as in the other, and the hydrogen must bear the same relations to the atomic ratio of the compound. Thus, if the mineral is an orthosilicate in which the atomic ratio between the *sum of the basic radicals* and the *silicon* is 1 : 1, all hydrogen in excess of the amount which this ratio requires must represent water of crystallization, while all required to complete the ratio must represent water of constitution; and we thus have a means of distinguishing between these two states of combination where the class of compounds to which the mineral belongs is known.

Now, it is true of each of the minerals we have distinguished among the vermiculites, —

First. That the water is driven off at a temperature below a red heat.

Secondly. That the loss of the water is attended with a complete disintegration of the mineral.

Thirdly. That the amount of the basic radicals, exclusive of the hydrogen, is sufficient to saturate the silicon, and that the amount of hydrogen is wholly in excess of the amount which the atomic ratio 1 : 1 requires.

Could it be proved that the vermiculites are orthosilicates, the last of the three facts just stated would be alone sufficient to establish the correctness of our conclusion. Unfortunately such absolute proof cannot be obtained; and we only claim that the crystallographic and chemical relations of the vermiculites to each other, and to the magnesian micas, gives a very high degree of probability to our theory that they are orthosilicates.

From these facts we have concluded that the water which enters into the composition of the vermiculites is water of crystallization. For the evidence of the facts, we refer to the descriptions of the several species given below. But, further, in order to justify our conclusion, we pro-

pose to bring into comparison with the vermiculites a class of hydrous micas from which the water obtained is clearly water of constitution, and this class of minerals we shall first describe.

Damourites. — Delesse originally gave this name to a hydrous mica which occurs in fine scales in Pontivy in Brittany. Since then, micas of similar composition have been observed in several countries, and shown to be not unusual constituents of granitic rocks.* Among these we may distinguish several varieties, (or species?) marked by slight differences of composition and optical characters. But we would propose to give the name Damourite to the whole class, distinguishing the varieties by separate names only so far as may be thought necessary, Under the family of Damourites, then, we class all unisilicate micas, which are chiefly silicates of aluminum and potassium, but in which a portion of the alkaline radical is replaced by hydrogen.

Sterlingite. — A remarkable mineral of the Damourite type is found at Sterling, Mass., associated with spodumene, in a vein of a large bowlder rock. This mineral, for the sake of distinction, I have called Sterlingite; but it does not differ from the original Damourite of Delesse except in the value of the optical angle. We give in parallel columns the characters of the two minerals: —

STERLINGITE.	DAMOURITE.
Mica-like in structure. An aggregate of flexible and unelastic laminæ, frequently an inch in diameter.	Mica-like in structure. An aggregate of fine scales.
Lustre, pearly.	Lustre, pearly.
Color, yellow or yellowish-white.	Color, yellow or yellowish-white.
$H = 2 - 3$.	$H = 2 - 3$.
Sp. gr. at 26°. 1st ex. gave 2.832. 2d " " 2.828.	Sp. gr. = 2.792.
Cleavage basal, highly perfect, as in mica. Jointed parallel to the sides of a rhomb, having an angle of 120°, and also parallel to the shorter diagonal of the same. The markings of these joints, or cleavages, visible on the surfaces of the laminæ.	
Double refraction strongly negative. Biaxial with plane of axes parallel to shorter diagonal. Divergence, about 70°. Dispersion of axes very small.	Double refraction negative. Biaxial divergence, 10 to 12 degrees.
Before the blowpipe fuses on the edges with potash flame.	

* See the papers of Professor Haughton, cited below.

ANALYSIS.

	Sterlingite.	Oxygen.	Damourite. 1.	Damourite. 2.	Oxygen.
SiO_2	43.87	23.40	45.22	43.41	23.15
Al_2O_3	36.45	17.00	37.85	35.17	16.39
Fe_2O_3	3.36	1.00		4.62	1.39
MgO				1.40	0.56
K_2O	10.86	1.84	11.20	10.90	1.85
H_2O	5.19	4.61	5.25	4.50	4.00
	99.73		99.52	100.00	

Of the two analyses of Damourite, No. 1 is by Delesse, of the mineral found in the gangue of cyanite, at Pontivy in Brittany, and No. 2 is by Igelström, of the similar mineral, found at Horrsjöberg, Wermland. The analysis of Sterlingite was made by Mr. C. E. Munroe, Assistant in the Chemical Laboratory of Harvard College, and the above numbers have been abundantly confirmed in repeated analyses by various students in the same laboratory. The alkalies were treated by Smith's process, and the potassium was weighed as PtK_2Cl_6. This value, compared with the total weight of the alkaline chlorides, and that of the chlorine also determined, showed that the alkali in the mineral was almost wholly potash, although the presence of lithium and sodium was plainly indicated by the spectroscope. The water was determined by igniting the mineral in coarse powder, previously dried at 100° C. Even after ignition, the finely pulverized mineral is only partially decomposed by hydrochloric acid, and in the above analysis it was decomposed by fusion with sodic carbonate. The usual tests failed to indicate the presence of fluorine.

Regarding the water as basic, and as forming a part of the protoxides, the atomic ratio in Sterlingite, between the silicon, the sesquioxide radicals, and the protoxide radicals, is

$$\overset{\text{IV}}{\text{Si}} : \overset{\text{VI}}{\text{R}} : \overset{\text{II}}{\text{R}} = 23.40 : 18 : 6.45, \text{ or nearly } 4 : 3 : 1.$$

The deviation from the simple ratio will not appear so great, as seems at first sight, if it is noticed that a difference of one-half per cent in the amount of water would make the ratio almost exact.

The corresponding ratio in the Damourite from Wermland is

$$23.15 : 17.78 : 6.41, \text{ or, as before, nearly } 4 : 3 : 1.$$

These ratios point to the general formula:—

$$\overset{\text{II}}{R}, \overset{\text{VI}}{\text{R}} . O_8 . Si_2.$$

The Damourite and Sterlingite are types of a very large class of hydrous micas, which in many places are widely distributed through the granitic rocks. This class of minerals has been especially investigated by Professor Haughton, of Dublin, whose papers may be found in Phil. Mag., IV. ix. 272, and Q. J. G. Soc., xviii. 414, also xx. 280. We cite here a few of his analyses, selected from those given by Professor Dana, — pages 310 and 311, of the fifth edition of his "System of Mineralogy," — in further illustration of the subject we are discussing:

DUBLIN CO. — HAUGHTON. Optical Angle, 58°.

$\ddot{Si}$	$\dddot{Al}$	$\dddot{Fe}$	$\dot{Mg}$	$\dot{Ca}$	$\dot{Na}$	$\dot{K}$	$\dot{H}$	
43.47	31.42	4.79	1.13	1.38	1.44	10.71	5.43	= 99.77
23.18	14.64	1.44	0.45	0.39	0.37	1.82	4.83	
23.18	16.09			3.03			4.83	
23.18	16.09					7.86		
3.	2.					1.		

MT. LEINSTER. — HAUGHTON. Optical Angle, 72°.

$\ddot{Si}$	$\dddot{Al}$	$\dddot{Fe}$	$\dot{Mg}$	$\dot{K}$	$\dot{H}$	
44.64	30.18	6.35	0.72	12.40	5.32	= 99.61
23.81	14.07	1.90	0.29	2.11	4.73	
23.81	15.97		2.4		4.73	
23.81	15.97			7.13		
3.	2.			1.		

GLENDALOUGH. — HAUGHTON. Optical Angle, 70°.

$\ddot{Si}$	$\dddot{Al}$	$\dddot{Fe}$	$\dot{Mg}$	$\dot{Ca}$	$\dot{Na}$	$\dot{K}$	$\dot{H}$	
44.71	31.13	4.69	0.90	1.09	1.27	9.91	6.22	= 99.92
23.84	14.51	1.41	0.36	0.31	0.33	1.68	5.53	
23.84	15.91			2.68			5.53	
23.84	15.91					8.21		
3.	2.					1.		

In these micas again, if we regard the water as basic, we obtain a nearly constant ratio, but differing from that of Damourite in the relation of the two basic radicals. The general symbol of the last would be: —

$$\overset{II}{R}_6, \overset{VI}{R}_4 . O_{36} . Si_9.$$

There appear to be, therefore, these two distinct types of hydrous micas related to the species Muscovite, all rich in alumina and alkali, destitute, or only containing very small amounts, of magnesia, and having a wide optical angle.

The anhydrous Muscovites have not been investigated nearly as fully as the hydrous varieties; and I can find no analyses of any of the beautiful specimens from our American localities. I cite here, for the sake of comparison, an analysis of the Fuchsite, from the Zillerthal, by Schafhäutl (No. 1), and one of a mica, from Fahlun, by H. Rose (No. 2): —

	$\ddot{Si}$	$\dddot{Al}$	$\dddot{Fe}$	$\dddot{Cr}$	$\dot{Mg}$	$\dot{Ca}$	$\dot{Na}$	$\dot{K}$	F	
(1)	47.95	34.45	1.80	3.95	0.71	0.59	0.37	10.75	0.35	=100.92
	25.57	16.05	.54	1.24	.28	0.17	0.09	1.83		
	25.57	17.83			2.37					

	$\ddot{Si}$	$\dddot{Al}$	$\dddot{Fe}$	$\dot{Mg}$.	$\dot{K}$	$\dot{H}$	F
(2)	46.22	34.52	6.04	2.11	8.22	0.98	1.03
	24.65	16.08	1.81	0.84	1.39	0.87	
	24.65	17.89		3.10			

If now we should add to (1) 6.93 per cent water, and to (2) 3.42 per cent, we should obtain the ratios: —

(1) 25.57 : 17.83 : 8.52, or approx. 3 : 2 : 1,

as in the hydrous micas analyzed by Haughton.

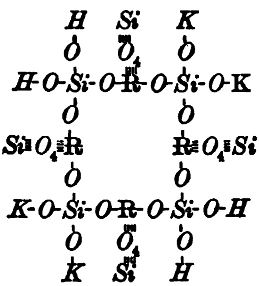
(2) 24.65 : 17.89 : 6.16, or approx. 4 : 3 : 1,

as in Damourite and Sterlingite.

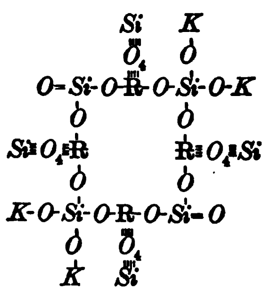
There would seem, then, to be two definite varieties of hydrous micas of the Muscovite family, distinguished by the atomic ratios 3 : 2 : 1 and 4 : 3 : 1. Corresponding to these, it is probable that there are two varieties of anhydrous mica, containing an excess of $Si\,O_2$, which, by the addition of sufficient water to saturate the excess of the acid radical, are reduced to one or the other of the two normal types. In a previous paper (Am. Jour. Sci., II. xii. 217, 1867) the author suggested the idea that the excess of silica in this class of micas might result from a mixture of two isomorphous species corresponding to the two hydrates: —

$$H_4{:}O_4{:}Si \text{ and } H_2{\cdot}O_2{\cdot}Si\,O,$$

and he there described a mica whose atomic ratio was very closely that of the second type, and which he called Cryophyllite. Now, the simplest theory of the relation of the hydrous to the anhydrous Muscovites would seem to be that, while in the molecules of the anhydrous micas a portion of the silicon atoms (the number varying in the different varieties) are in the condition of the first anhydride ($H_2{=}O_2{=}Si\,O$), the hydrous micas contain sufficient basic hydrogen to bring all the silicon atoms into the condition of the normal hydrate ($H_4{\equiv}O_4{\equiv}Si$). The two graphic formulæ which follow indicate, more clearly than any other language can, the relations we have attempted to describe. In these formulæ $\mathbf{R}$ stands for the double atom in the radical of the sesquioxides, having the quantivalence of six: —



Hydrous Muscovite.



Anhydrous Muscovite.

The new mineral Sterlingite, whose examination has been the occasion of this discussion, is remarkable as being a very well-defined example of a hydrous mica occurring in large crystals, and exhibiting very marked characters. It does not materially differ in composition from Damourite, and it also agrees with the specimens of this mineral so closely in other physical qualities that we cannot regard the small

optical angle, observed by Descloizeaux on the minute scales of the Pontivy mica, as sufficient ground for separating the new mineral from the old species. We should include under this species all hydrous micas which are rendered by the basic hydrogen orthosilicates, and to it the name Damourite belongs by priority. Sterlingite is simply a variety of Damourite, having the ratio 1 : 3 : 4, with more marked qualities and a wider optical angle than the Pontivy mineral; and, provisionally, the name I have given will be useful in designating it.

The hydrous micas, of which Sterlingite is a variety, have a special interest in connection with the subject of this paper, because they illustrate the characteristics of basic water, which will be contrasted, with those of water of crystallization, in our description of the following species. The evidences that the water in these micas is basic, — that is, forms a part of the basic radical, — may be summed up as follows: —

1. The amount of water in the different varieties is very variable, and bears no constant ratio to that of the other basic radicals.*

2. The hydrogen of the water supplements the other basic radicals and fills out the amount required for a unisilicate, the type to which most of the micas conform.

3. The water is expelled only at a very high temperature.

4. The loss of water is not attended with any marked change in the appearance of the mineral.†

Jefferisite, of *West Chester*. — This well-known mineral, found in the serpentine at West Chester, Pa., was, as I have said, carefully analyzed by Professor Brush, of New Haven, who named it after W. W. Jefferis, Esq., of West Chester; and to this gentleman I am indebted for the specimens of the mineral whose crystallographic relations I have studied. As I am informed by this careful mineralogical observer, the locality is some three miles south of West Chester, where

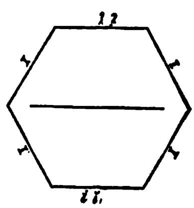
* This fact is not shown so forcibly by the analysis cited above as by the series given by Professor Dana, on pages 310 and 311 of the fifth edition of his "System of Mineralogy," to which we would refer in illustration of this point.

† Since the above was written, we have received from Dr. F. A. Genth his very valuable paper on corundum and its associated minerals. He regards Damourite as one of the most important products of the alteration of corundum, and gives a large number of analyses of specimens from different localities, to which we gladly refer, as they illustrate the point made in this paper, even more markedly than the analyses cited above. The Damourites are evidently widely distributed minerals and characteristic features of certain rocks.

the mineral occurs in several veins or pockets of the serpentine, not more than fifty yards from the quarry where the ripidolite is found. It is associated with oligoclase; and corundum also occurs in the same serpentine formation, in Newton township, ten miles distant, on the north edge of the serpentine ridges. The Jefferisite is found in broad crystals, or crystalline plates, which frequently have a distinct hexagonal form. On two of these plates sent me by Mr. Jefferis, measuring respectively two inches and three-fourths of an inch in diameter, the form is as sharp as on crystals of Muscovite, and the edges make an angle of 120°, as nearly as it can be measured. Mr. Jefferis writes, — "In regard to the Jefferisite crystals which you have examined, the large crystals or plates occurred in the vein immediately under the sod, exposed to all frost, &c.; the small crystals were taken out four or five feet below, in the decomposed Deweylite, and were associated with striated oligoclase, of which I sent you specimens."

The crystals of Jefferisite cleave like mica, affording thin but unelastic foliæ. The cleavage planes are marked triangularly by lines, crossing at angles of 60° and 120°. In some cases there is a jointing as in crystals of mica, parallel to the shorter diagonal of the rhomb. One crystal sent me by Mr. Jefferis is the half of a rough hexagonal prism, an inch and a quarter high by two inches in diameter. The plane of the optical axes, as in the larger number of micas, is parallel to one of these lines, as indicated in Fig. 1, coinciding with the shorter diagonal of the rhombic prism, which appears to be the fundamental form in all this class of minerals, and from which the hexagonal form is derived by the truncation of the two acute angles. The double refraction is strongly negative, but the angle between the optical axes varies in the most remarkable manner. I have measured angles on different plates, of 27°, 24°, and 10°, and observed many intermediate conditions. Owing to the deep yellow color, the plates become opaque at a very moderate thickness, and for this reason it is impossible to measure the angle with great precision. Some of the plates are apparently uniaxial; but this may result from the blending of the two hyperbolas, due to the thinness of the plate. The dispersion of the axes is but slight, and only perceptible in the thicker laminæ when $\rho < v$. It is obvious, therefore, that the crystallographic characters of the mineral are identical with those of mica.

Fig. 1.



The plates are generally, if not invariably, twinned, and the twin-

ning is the cause of this most remarkable variation in the optical angle, as will be explained at length in connection with our description of Culsageeite. On this last mineral the same phenomena are more marked, owing chiefly to the greater transparency of the plates.

In order to illustrate the chemical relations of the mineral to the Biotite micas, we give below: 1st. The results of the analysis of Jefferisite by Professor Brush. 2d. The same results, calculated for the anhydrous mineral. 3d. The results of an analysis of a Biotite mica, from Pargas, Finland, by Svanberg. In each case I have added the amounts of oxygen in the several oxides, to show the atomic ratios: —

	$\ddot{\text{Si}}$	$\dddot{\text{Al}}$	$\dddot{\text{Fe}}$	$\dot{\text{Fe}}$	$\dot{\text{Mg}}$	$\dot{\text{Ca}}$	$\dot{\text{K}}$	$\dot{\text{H}}$	
(1)	37.10	17.57	10.54	1.26	19.65	0.56	0.43	13.76	= 100.87
	19.78	8.18	3.16	.28	7.86	.16	.07	12.23	
	19.78	11.35		8.37				12.23	
	5.	3.		2.				3.	

	$\ddot{\text{Si}}$	$\dddot{\text{Al}}$	$\dddot{\text{Fe}}$	$\dot{\text{Fe}}$	$\dot{\text{Mg}}$	$\dot{\text{Ca}}$	$\dot{\text{K}}$	
(2)	42.94	20.33	12.20	1.46	22.75	.66	.50	= 100.84
	22.90	9.47	3.66	.32	9.10	.19	.08	
	22.90	13.13		9.69				
	5.	3.		2.				

	$\ddot{\text{Si}}$	$\dddot{\text{Al}}$	$\dddot{\text{Fe}}$	$\dot{\text{Mn}}$	$\dot{\text{Mg}}$	$\dot{\text{Ca}}$	$\dot{\text{K}}$	$\dot{\text{H}}$	F	
(3)	42.58	21.68	10.39	.75	10.27	1.04	8.45	3.35	.51	= 99.01
	22.71	10.10	3.12	.17	4.11	.30	1.43	2.98		
	22.71	13.22		8.99						
	5.	3.		2.						

The general symbol of Jefferisite deduced from (1) would be, —

$$\overset{\text{II}}{R}_4, \overset{\text{VI}}{R}_2 . O_{20} . Si_5 . 6H_2O.$$

A comparison of the results given in (2) and (3) will show that the anhydrous Jefferisite corresponds very closely in its chemical constitution with the Biotite mica from Pargas. The chief difference is to be found in the fact that the mica contains potassium and basic hydrogen, in place of more than one-half of the magnesium of the Jefferisite. It should, however, be remembered in this connection that the Biotites present a very wide variation in the ratio between the amounts of the

protoxide and sesquioxide radicals which the various varieties contain. The limits usually assigned to this variation correspond to the ratios —

$$\overset{\text{II}}{\mathrm{R}} : \overset{\text{VI}}{\mathrm{R}} : \mathrm{Si} = 1 : 2 : 3, \text{ and } \overset{\text{II}}{\mathrm{R}} : \overset{\text{VI}}{\mathrm{R}} : \mathrm{Si} = 1 : 1 : 2,$$

and the Pargas mica with the ratio 2 : 3 : 5 falls between these limits; but the Culsagee variety of vermiculite corresponds to the more common class of Biotites, which have the ratio 1 : 1 : 2.

But this resemblance in chemical constitution only appears when we compare the Biotite mica with the anhydrous Jefferisite; while it is the crystallized hydrous Jefferisite which so closely resembles the magnesian micas in its crystallographic relations; and the question now arises, What is the condition of the large amount of water — 12½ per cent — which the crystallized mineral contains?

To aid us in forming a conclusion on this point, we have the following evidence:—

First. As the above analysis shows the water is united in definite and atomic proportions amounting to six molecules to every five molecules of silicon in the molecules of the mineral, that is sufficient to convert all the silicon into a hydrate, assuming that the five silicon atoms in this hydrate are joined to each other by the smallest possible number of bonds.

Secondly. While both the crystallographic and the chemical relations of Jefferisite to the other vermiculites, and to the magnesian micas, indicate that the mineral is an orthosilicate, the amount of basic radical, exclusive of the water, is amply sufficient to saturate the atomicity of the silicon.

Thirdly. It was observed by Professor Brush — and his observations have been fully confirmed by ourselves — that the water is given off at a comparatively low temperature, — about 300° C.; and, as every mineralogist knows, this dehydration is attended with that remarkable exfoliation which is characteristic of the vermiculites, and indicates a complete disintegration of the molecular structure. This exfoliation is wholly different from the phenomena which the so-called hydrous micas present under like conditions. In these last — which, as we suppose, contain hydrogen as a part of the basic radical of their molecules — a very high temperature is required to expel the water, and the loss is attended by no such marked change of volume and disintegration.

The conclusion that we draw from these facts is, that the combined water is in the same condition in Jefferisite as in the zeolites, and in many crystallized salts, — a condition which has long been known in chemistry as *water of crystallization.* We shall not here attempt to

discuss what are the relations of the water thus combined to the molecular structure of the mineral. This question is still in suspense, and we are persuaded that our science is not yet in a condition to solve the problem. All that we can at present do is to classify the phenomena presented by the exfoliation of the vermiculite minerals with the efflorescence of Glauber's salt or the intumescence of alum.

If, then, I am justified in the inferences I have drawn, Jefferisite differs chemically from Biotite mica chiefly in containing water of crystallization, very much in the same way that gypsum differs from anhydrite, or common salt from the crystals with two molecules of water, which form in brine at a low temperature. In these bodies, however, the forms of the crystals of the hydrous are wholly different from those of the anhydrous salts, while the crystallographic relations of Jefferisite are very similar, if not identical, with those of the magnesian micas. It is, however, also true that the crystalline structure of the micas seems to admit of a very wide variation of chemical composition. In cryophyllite, which has all the crystallographic characters of the micas strongly developed, is the atomic ratio 3 : 4 : 14; while in the Biotite, whose analysis was cited above, it is 2 : 3 : 5. The first is an acid, and the last a neutral silicate. The other varieties of mica have a composition intermediate between these extremes; and it might be said, if such a variation of composition is compatible with the crystalline structure exhibited by this group of minerals, it would not be surprising if the structure were sufficiently elastic to admit of the insertion of the water of crystallization without great alteration of external form.

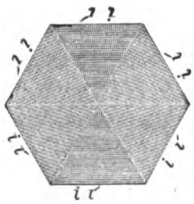
It may be further urged that the normal mica crystal (a rhombic prism with angles of 60° and 120°) is a form which appears to be related to a mode of molecular structure common to a great many substances, and the phenomena which will be described in this paper seem to sustain this opinion. Still, we do not care to theorize about the subject. Our object is simply to make prominent the two points: 1st. That the crystallographic structure of Jefferisite is identical with that of the magnesian micas. 2d. That the chemical constitution of the anhydrous mineral is closely allied to that of Biotite.

Culsageeite or the Vermiculite of the Jenks Mine, North Carolina.— Through the kindness of Colonel C. W. Jenks, the proprietor of the corundum mines on the Culsagee River in Macon County, N. C., I have had an opportunity of examining a variety of vermiculite which at that locality forms an important part of the matrix of the corundum. The associations of the mineral in North Carolina are very similar to those

in Pennsylvania. Professor J. Lawrence Smith, in his recent article in Am. Jour. Sci. (III. vi. 180), says that "in the development in North Carolina the corundum" (with which the vermiculite is associated) "occurs in chrysolite or serpentine rocks, and outside of serpentine it has not been found. These chrysolite rocks belong to a regular system of dikes which have been traversed for the distance of about one hundred and ninety miles. This system of dikes lies on the north-west side of the Blue Ridge, and has a strike parallel to the main mass of the ridge, and has an average distance from the summit of the ridge of about ten miles. The serpentine appears at intervals along this whole line of one hundred and ninety miles," and "is usually enclosed in a hard crystalline gneiss." In the serpentine the corundum has been found at several localities along a distance of forty miles. Colonel Jenks writes me: "The workmen have opened a new vein they call the gem vein. It is walled with chrysolite, and the fissure is from one to four feet wide, which fissure is filled with ripidolite, and in this the corundum crystals are imbedded." As regards the association of the ripidolite and vermiculite, he also writes: "They occur both alone and intermingled, and also in layers, like the leaves of a book." Again: "The ripidolite maintains a uniform character of texture and appearance, whether associated with the vermiculite or alone. In the vein at the bottom of the shaft I have spoke of, and elsewhere, it is of uniform hardness, texture, &c., but in it the corundum seems to have lost cohesion, — in some localities falling to pieces, and crumbling out of the ripidolite matrix. But, when exposed to the air and sunshine for a day or two, the corundum regains its cohesion, and you can then chip off the ripidolite from it. It is just the opposite with the vermiculite when alone the matrix. Sometimes it occurs in masses, several feet long, formed of scales as large as your hand, easily separating like mica from the corundum, which in this matrix always seems to retain its cohesion. Then, again, the vermiculite will occur in masses of many bushels, all broken up and disintegrated, like very coarse bran, in which the crystals of corundum lie like eggs in a box of sawdust. The great crystal (weighing 316 pounds) was thus deposited. At other places the entire mass seems to have changed to the color of white Castile soap, with specks of green in it, the corundum crystals all falling apart until exposed, when they harden." This untechnical language of an unprofessional but accurate observer conveys a very vivid idea of the mode of association of these minerals. The specimens so kindly sent me by Colonel Jenks confirmed in all respects his observations. In several cases the corundum was still imbedded in both the ripidolite and the

vermiculite, and the scales of these minerals not unfrequently penetrated the corundum crystals in such a way as to indicate that the corundum had crystallized around them. The ripidolite is firm in texture, and closely resembles the variety from West Chester. It occurs in hexagonal plates, which have a striation similar to that I formerly described as characteristic of the Pennsylvania specimens (Am. Jour. Sci., II. xliv. 201, 1867), and which is illustrated by Fig. 2. Professor Smith, *loc. cit.*, gives analyses of two varieties of ripidolite — one compact, the other friable — as follows:—

Fig. 2.



COMPACT RIPIDOLITE FROM NORTH CAROLINA.

$\ddot{\mathrm{Si}}$	$\dddot{\mathrm{Al}}$	$\dddot{\mathrm{Fe}}$	$\dot{\mathrm{Mg}}$	$\dot{\mathrm{H}}$	
27.00	21.60	16.63	22.00	12.30	= 99.53

FRIABLE RIPIDOLITE FROM NORTH CAROLINA.

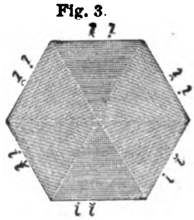
$\ddot{\mathrm{Si}}$	$\dddot{\mathrm{Al}}$	$\dddot{\mathrm{Fe}}$	$\dot{\mathrm{Mg}}$	$\dot{\mathrm{H}}$	
29.15	10.50	23.50	25.44	10.04	= 98.63

A determination of the silica in the compact mineral made by Mr. F. Gooch, student in the Laboratory of Harvard College, gave 27.25 per cent of SiO_2, and 11.93 H_2O, as a mean of two closely agreeing determinations. But in the specimens sent me by Colonel Jenks I did not recognize the friable variety.

The vermiculite occurs in close contact with the ripidolite, and is frequently interlaminated with it, *but the two are always perfectly distinct*, thus entirely disproving the theory that the vermiculite was derived from the ripidolite by weathering. It occurs in large plates having more or less of an hexagonal outline. Some of those received from Colonel Jenks were five inches in diameter. It has a greenish-yellow color, which is very much lighter than that of the West Chester variety. The plates are strongly marked by lines crossing at angles of 60° and 120°, like those from West Chester; but these lines are more marked in the North Carolina variety. This variety is also much more friable than the other, and readily breaks in directions parallel to these lines,—yielding rhombic plates with angles of 120° and 60°, and more readily hexagonal or triangular plates, produced by the truncation of the 60° angle of the rhombic plate, on a line parallel to the shorter diagonal of the fundamental rhomb. The plates most readily break

parallel to this diagonal, and, like the specimens from West Chester. are frequently jointed in this direction. Like other micaceous minerals, the plates cleave readily parallel to the basal plane, yielding very thin foliæ, exceedingly flexible, but not elastic. The optical characters are the same as those of the West Chester variety, — strong negative double refraction yielding a biaxial ring system, with uniform distribution of colors, and very variable optical angle. I have measured angles from about 30° to about 13°. The angle often varies widely in different parts of the same plate. Thus I have measured on different laminæ, from a single plate not exceeding 3 inches in diameter, the three angles 30°, 24°, and 13°; and again I have noticed a similar variation on one and the same lamina. Indeed, the phenomena which I observed were almost identical with those I had previously observed on plates of ripidolite from Texas, Pennsylvania, *loc. cit.* On moving the lamina just referred to parallel to itself, in front of the polarizing microscope, the optical angle varied as I passed from one side of the field to the other. Beginning with a value of about 30°, the angle decreased to about 13°. Moving the plate still further, I found a region of indistinctness, and then the axes opened again, — the new plane making an angle of 120° to the old. I had evidently here a macling precisely similar to that I had previously described in the Texas ripidolite, and shown in Fig. 3, where the lines of shading represent the position of the plane of the optical axes. This represents what we may call an ideal macle; for I have seldom been able to trace more than three individuals on the same plate, and, as a rule, these are very unequally developed. On many of the specimens of the North Carolina vermiculite, the macling is externally marked by the eminent cleavage or jointing parallel to the shorter diagonal of the rhomb section, and in several of the specimens I have examined it was quite symmetrical. A study of these specimens led me to an explanation of the cause of the remarkable variation of the optical angle, which I believe not only applies to the vermiculites and ripidolites, but also, in many cases at least, to the micas. It would be expected that the several members of such macles as Fig. 3 represents would penetrate each other, and I therefore made a series of experiments to ascertain what would be the effect of the interfoliation of laminæ in which the planes of the two sets of optical axes had the same relative position as in the several members of the macle. To that end I divided a plate, which presented the largest optical angle I had observed, into as thin laminæ as possible, and then superimposed them in the relative

Fig. 3.



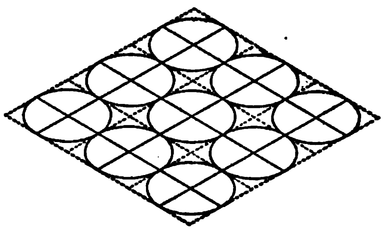
position I have mentioned, so that the planes of the optical axes should be inclined at an angle of 60°. The result was — when the thickness of the plates in each position were nearly equal — that a symmetrical ring system was obtained, in which the optical angle was about 13°, — the smallest I had measured; and, by varying the relative thickness, intermediate degrees of optical divergence were produced. By now introducing laminæ into the compound crystal, in the position of the third member of the macle, — that is, with the plane of the optical axes in the position of the third diagonal of the hexagon, — the apparent angle could be reduced still further, so that the plate was apparently uniaxial. Although these experiments were sufficient to show that the macling was an adequate explanation of the apparent variation of optical angle I had observed in the plates of ripidolite and Jefferisite, they also raised the question how far the effect I had obtained in my experiments might be due to the circumstance, that, on account of the deep color of these minerals, it is only possible to experiment on very thin plates, with which, of course, the rings of interference are very wide, and the hyperbolas proportionally indefinite. I therefore next made a similar experiment with a well-known phlogopite mica from Jefferson County, N. Y., whose crystals are very distinctly macled after the type of Fig. 3 or 5, the plates presenting a variation of optical angle similar to that I have described, the normal axial divergence being about 15½°. A very clear portion of one of these plates was first cut into a regular hexagon, one of whose diagonals was in the plane of the optical axes. This hexagonal plate was then split into twelve laminæ, which were superimposed with the intervention of balsam, and in alternating positions, like the members of a macle, — the optical plane in each of the laminæ making an angle of 60° with that of the lamina above or beneath it. The result was an essentially uniaxial plate, differing from a plate of uniaxial mica only in small irregularities in the contour of the rings, such as the lamination would be expected to produce. On repeating now this experiment with a Muscovite mica having a wide optical angle about 63°, I obtained a most remarkable and unexpected result, — a structure presenting optical phenomena similar to those of a plate of quartz cut perpendicularly to the principal axis. At the first trial I obtained a compound mica plate showing a disk of color in the centre of the field whose tint changed during the rotation of the analyzer, — of the polarizing microscope, — like a plate of left-handed quartz; and, on superposing a plate of right-handed quartz, the spirals of Airy at once appeared. The rings, however, were wholly broken up, and appeared only in irregular

patches of color. This irregularity was due to the unequal thickness of the laminæ employed, and I found it impossible to split up one and the same hexagonal plate of mica into laminæ, which were sufficiently uniform for the purpose. But very satisfactory results were obtained in the following way. I selected for the purpose the very clear and easily cleavable mica from Grafton, N. H.; and, after a few trials, succeeded in cleaving off very thin plates of considerable size and nearly uniform thickness. Selecting one of these plates, I first divided it by means of a parallel ruler into strips, and from these strips cut out the hexagonal laminæ by means of a steel pattern carefully made. The thin mica can be cut with perfect accuracy by a sharp knife on a plate of glass. The hexagonal laminæ thus obtained, though coming from different parts of the mica plate, were optically parallel to each other; and by drawing at the outset a line, with a sharp point, near the corresponding edges of the several strips, this line served as a guide for placing the hexagonal laminæ. From laminæ thus prepared, plates were made showing the familiar system of rings as perfectly as could be expected. The best results were obtained with plates consisting of from twelve to twenty-four laminæ; and the character of the resulting plate, whether left or right handed, was found to depend on the order of the spiral arrangement. If in building up the pile the marked side of each successive lamina is turned through an angle of 60° in the direction of the motion of the hands of a watch, the result corresponds to left-handed quartz if turned in the reverse direction to right-handed, and on superposing two dissimilar plates thus prepared I obtained again the spirals of Airy in great perfection. Thus, then, it appears that, even with micas of the widest optical angle, we can build up a structure which is optically uniaxial.*

* The great difficulty in preparing these plates is to obtain thin films of mica of uniform thickness, which are of sufficient size to yield a dozen or more laminæ; and the more nearly we have succeeded in preparing such a film, by splitting sheets of mica, the more closely we have been able to imitate the phenomena seen under like conditions with a plate of quartz. We have been able to work with films which measured with a spherometer only $\frac{1}{400}$ of an inch in thickness, and have not obtained good results with those which were much thicker, and when thinner than this the mica cannot readily be cut into shape. The least inequality in the thickness of the several laminæ composing the same plate more or less mars the effect; and, although some of the striking features seen with quartz may remain, such as the succession of colors on revolving the analyzer, and even the spirals of Airy, yet the more delicate phases of the phenomena disappear. The plate changes color when revolved in its own plane, the rings lose their circular form and become confused, and the violet cross disappears. Moreover, as regards the conditions which determine the phase of the circular polarization, the law stated above can only be affirmed with cer-

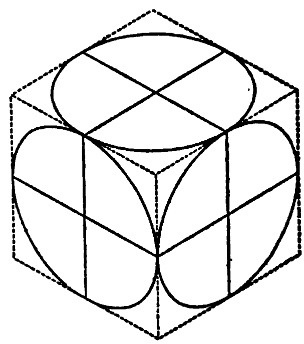
The theory which I have formed to account for these facts is as follows. We may conceive that the molecule of mica is an ellipsoid, whose elliptical section, through the longer axis, can be inscribed in the rhomb of 60° and 120°. Assume now that these molecules have polarity, the rhombic prism would be the normal result of their association, as represented in Fig. 4.

Fig. 4.



We may, however, conceive that three of these molecules may become associated by alternate single poles to form a nucleus, such as represented in Fig. 5. Such a group once formed would be in a condition of great stability, resulting from the concurrent action of the several poles; and if now each of the molecules develops into a crystal, the result would be a macle of a form which is very common in the mineral kingdom. If six molecules unite in a similar way to form a nucleus, as in Fig. 6, we should also have stable equilibrium (although less firm than before), and the result of a symmetrical development would be a macle such as has been represented in Figs. 2 and 3. Whether this more complex arrangement is necessary in order to explain the phenomena presented by

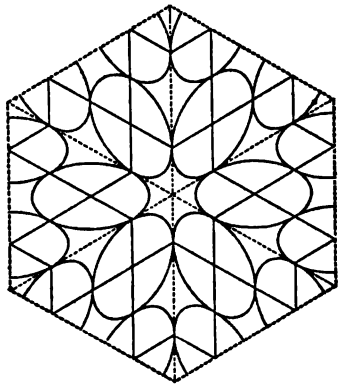
Fig. 5.



tainty of plates consisting of laminæ which very nearly fulfil the conditions we have described. Very small inequalities of thickness renders the effect irregular, and made it at first difficult to discover the law. Our experiments have been a series of approximations; and, although we may never be able with our rude appliances to compete with nature in the manufacture of uniaxial crystals, yet we have approached so near to the perfect result as to be able to point out with confidence one way, at least, by which the effects seen in natural crystals may be produced. We have usually cut the laminæ into regular hexagons, but equilateral triangles might more easily be cut, and would probably give as good results; for, although the errors of position might not be so well distributed, we have found that a slight variation in the relative position of the laminæ injures the result to a far less degree than the least inequality in their thickness. It still remains to make careful quantitative measurements of the effects produced under determinate conditions; and, as can easily be seen, the subject opens a wide field for mathematical analysis as well as physical investigation.

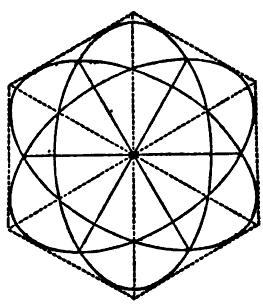
the vermiculites and micas, I do not feel confident. It is seldom that more than three individuals can be distinguished on a given plate; and the very unequal development of the several individuals, and the indefiniteness of the lines of demarcation, resulting from the phenomena which have been described, render what would seem to be a characteristic feature of the more complex group not necessarily a certain indication of the structure. I refer to the fact, very constantly noticed, that the plane of the optical axes is parallel to the nearest hexagonal edge, as shown in Figs. 2 and 3. In Figs. 5 and 6 this same plane is parallel to the shorter axis of the ellipse; and it can easily be seen that if either of the individual of Fig. 5 were developed over any large portion of the space of its neighbors, the optical plane might appear parallel to the adjacent edge.

Fig. 6.



Having made the two suppositions, as above, to explain the phenomena of twinning, which have been long familiar and externally visible, it will not, we trust, appear unreasonable if we make a third supposition to explain the phenomena first described in this paper. We may conceive that the ellipsoidal molecules, instead of grouping together on the same plane, become associated by their alternate poles, one over the other, as represented in Fig. 7. Molecules so associated, developing laterally, would produce the laminæ of a mica plate in the relative position in which we have placed them in our artificial crystals, with only this difference, that the laminæ would be indefinitely thin, and in exact position; and the effect of such compound molecules in modifying the elasticity of the crystalline structure must be, in most respects at least, like that of single molecules, symmetrical on all sides of one line or axis,—in other words, they must produce a structure similar to that of uniaxial crystals. Under what further conditions the grouping of

Fig. 7.



the molecules, in right or left handed spirals, determines the phenomena of right or left handed circular polarization, and what bearing the new facts may have on the received theory of these phenomena as they appear in quartz, must be left for further analysis to discuss.

I pass next to consider the composition of the Culsagee vermiculite, and I give below, at (1), (2), and (3), the results of three analyses, made by myself, together with the corresponding oxygen ratios.

The pulverized mineral, after it has been exfoliated by heat, is easily and perfectly decomposed by hydrochloric acid. In analysis (1), after the separation of the silica, the alumina and ferric oxide were separated from the magnesia by ammonia, with the usual precautions. In (2) and (3) the bases were converted into nitrates and separated by Deville's method. In each case the magnesia was weighed as pyrophosphate, and the alumina and ferric oxide were weighed together.

All three analyses were made with material rendered anhydrous by ignition until the weight was constant, and each is represented by three distinct determinations; namely, the weight of the silica, the sum of the weight of the alumina and ferric oxide, and the weight of the magnesic pyrophosphate. The oxides of iron and the water were once for all determined on separate portions of the dried but not exfoliated mineral, and therefore appear of the same value in all the analyses.

The determination of the water was the only difficulty which the analysis of this mineral presented. It is by far the most hygroscopic silicate I have ever examined, when once dry absorbing water from comparatively dry air with almost as much avidity as chloride of calcium. In two experiments with different portions of the same powder, the material was heated in an air bath, at 100° C., for seventy-two hours before the weight became constant; and in each case the weight was compared at intervals of about six hours. The total loss in the first experiment was 10.27 per cent, and in the second 10.19 per cent. The mineral thus dried lost when ignited 10.84 per cent. Another portion of the same powder, which had been dried over sulphuric acid for more than two months, lost when ignited 11.09 per cent. This close agreement indicates that all the water lost in drying, either at 100° or over sulphuric acid, is hygroscopic; and the conclusion is confirmed very greatly by the fact that the mineral in thus drying does not change its aspect in the least degree, and rapidly reabsorbs the water when exposed to the air. On the other hand, when the mineral is ignited it swells up to many times its volume, like other members of the vermiculite family, and undergoes what is evidently a profound alteration in its molecular structure.*

* In his valuable paper on corundum, above referred to (p. 44), Dr. Genth

	$\ddot{\mathrm{Si}}$	$\dddot{\mathrm{Al}}$	$\dddot{\mathrm{Fe}}$	$\dot{\mathrm{Fe}}$	$\dot{\mathrm{Mg}}$	$\dot{\mathrm{H}}$
(1)	37.58	19.73	5.95	0.58	25.13	11.09 = 100.06
	20.04	9.19	1.78	0.14	10.05	9.86
	20.04	10.97		10.19		9.86
	2.03	1.11		1.03		1.
(2)	37.43	19.75	5.95	0.58	25.58	11.09 = 100.38
	19.96	9.20	1.78	0.14	10.23	9.86
	19.96	10.98		10.37		9.86
	2.03	1.11		1.05		1.
(3)	37.10	20.22	5.95	0.58	25.07	11.09 = 100.01
	19.79	9.42	1.78	0.14	10.03	9.86
	19.79	11.20		10.17		9.86
	2.	1.13		1.03		1.

has published two analyses of the Culsagee vermiculite, made in his laboratory by Mr. Chatard and Dr. Koenig. Their results agree very closely with those given above, except in the amount of water; and since, as Dr. Genth states, the analyses were made with material which had been dried *in vacuo* over sulphuric acid for only four days, it is obvious that they have estimated as combined water a large portion of what we, for reasons stated, have regarded as hygroscopic moisture. Reducing their results to the same standard as our own, the close agreement becomes evident. We give, for comparison, first the results, as published; second, the same reduced to a water percentage of 11%; third, the corresponding oxygen or atomic ratios.

	$\ddot{\mathrm{Si}}$	$\dddot{\mathrm{Al}}$	$\dddot{\mathrm{Fe}}$	$\dot{\mathrm{Fe}}$	$\dot{\mathrm{Ni}}$	$\dot{\mathrm{Mg}}$	$\dot{\mathrm{H}}$
Mr. Chatard.	33.93	17.38	5.42	0.50	0.85	23.48	19.17 = 100.18
	37.83	19.12	5.94	0.55	0.88	25.77	11.09
	19.91	8.91	1.78	0.12	0.07	10.81	9.86
	19.91	10.69			10.50		9.86
	2.02	1.06			1.05		1.
Dr. Koenig.	33.77	17.56	5.61	0.50		22.48	20.30 = 100.22
	37.65	19.58	6.26	0.56		25.06	11.09
	20.08	9.12	1.88	0.12		10.02	9.86
	20.08	11.00			10.14		9.86
	2.04	1.11			1.03		1.

The close agreement of these results with our own, obtained by different processes and with different specimens of the mineral, indicates a remarkable constancy of composition for a micaceous mineral. I have confirmed Dr. Genth's observation of the presence of a very small amount of nickel in the mineral, and I also detected in it a trace of copper.

It is evident from these analyses that the atomic ratio of the mineral is 2 : 1 : 1 : 1, and its formula may therefore be written: —

$$R_3, \text{R} . O_{12} . Si_3 . 3H_2O.$$

By referring to what has already been said of the relation of Jefferisite to the Biotites, it will be seen that, while that mineral corresponds to a less common variety of this species, the Culsagee vermiculite corresponds to its more usual type. We give below, at (1), the results of an analysis of Vesuvian Biotite, by Chodnef; and, at (2), the same, assuming that a portion of the iron is in the ferrous condition, as is well known to be the case, in order to show that values within the probable error of the analysis would give the ratio 2 : 1 : 1. Here, of course, the alkali takes the place of a portion of the magnesia of the vermiculite.

	$\ddot{\text{Si}}$	$\dddot{\text{Al}}$	$\dddot{\text{Fe}}$	$\dot{\text{Fe}}$	$\dot{\text{Mg}}$	$\dot{\text{Ca}}$	$\dot{\text{K}}$	
(1)	40.91	17.19	11.03		19.04	0.30	9.96	= 98.43
(2)	40.91	17.19	7.03	4.00	19.04	0.30	9.96	= 98.43
	21.82	8.30	2.11	.89	7.62	0.09	1.69	
	21.82	10.41		10.29				
	2.12	1.01		1.				

This new variety of vermiculite is so well marked, and the composition so definite, that I have thought best to designate it by the name Culsageeite. As regards its other characters, it has a specific gravity of 2.225 (taken in alcohol), and about the hardness of talc. Before the blowpipe the exfoliated mineral fuses readily to a white enamel, but does not fuse in the flame of a Bunsen lamp.

To this variety of vermiculite belongs, as I have already intimated, the original mineral from Millbury, analyzed by Crossley. There can be no question as to the general accuracy of Crossley's results; and, assuming that all the iron is in the ferric condition, they give, as I have shown, almost precisely the atomic ratio 2 : 1 : 1 : 1. The only question that can arise is in regard to the condition of the iron. I have therefore made an assay of the iron by the accurate method I formerly described in the Am. Jour. Sci., xliv. 347, 1867. One hundred parts of the massive mineral gave 7.40 per cent ferric oxide, and 3.86 per cent ferric oxide, which corresponds to a total of 10.56 ferrous oxide. Crossley found 10.02 ferrous oxide, but he separated with great care the vermiculite from the steatite with which it is mixed; and this steatite was probably the source of the greater part of the small quantity of ferrous oxide found in our assay, which, though not made with

pure material, shows conclusively that the condition of the iron in the Millbury vermiculite is not different from that in other varieties of the same family of minerals.

Hallite. — Several years since this variety of vermiculite was sent to me by Mr. John Hall, of Philadelphia, by whom it was originally discovered. The examination then made showing that the mineral was a new variety, if not a new species, of the vermiculite family, I gave to it the name of Hallite, in recognition of the mineralogical services of Mr. Hall, who not only discovered the mineral, but has carefully worked the locality and observed the associations in which it is there found. A preliminary notice of the mineral under this name was published at the time by Professor Leeds, of Hoboken; but the interesting relations which the mineral bears to the subject of this paper have made a further examination desirable.

Hallite occurs in large rough six-sided prisms, with easy micaceous cleavage. There are two varieties, differing markedly in color, green and yellow; and I am indebted to Mr. Hall for the following facts in regard to the locality and associations of this species. Mr. Hall writes: "The mineral is found at East Nottingham, in the serpentine formation of south-eastern Pennsylvania, three miles south of Oxford, in Chester County; and I know of no other locality. I think the green and yellow varieties are very closely related, and may possibly pass from one into the other; but I have no positive proof that they do. The crystals are found in nests or pockets, and the two colors are not found in the same nests. The green crystals are imbedded in a steatite earth or base of the same color as the crystals, and the yellow in a yellow earth; and sometimes nests, containing the opposite varieties, are only a few feet apart in seams of the serpentine rock."

As the following analyses show, the two varieties have essentially the same composition, and the only difference that could be detected was in the degree of oxidation of the iron. The yellow crystals appeared to be more weathered than the green, and on the last the green color frequently fades out towards the centre of crystals, thus giving indications of a metamorphosis by which one variety may pass into the other.

Under the microscope these scales of the mineral show a remarkable appearance. Between the greenish or nearly colorless plates are seen elongated scales of a yellow mineral resembling closely in color thin scales of Jefferisite. They are more or less spear-shaped in form, although usually very narrow, and lie accurately in parallel lines, which cross at angles of 60° and 120°, like the magnetic oxide of iron in the Muscovite from Pennsbury, Pa., or the microscopic crystals in the

Biotite of South Burgess of Canada; and the phenomenon of asterism, seen so beautiful with the plates of the last, can also be seen with thin laminæ of Hallite. It was impossible to free the mineral from this admixture, but specimens were selected for analysis as free from it as possible. It was also impossible to determine its exact nature. The scales had not a definite form, but there was a tendency to a rhombic shape, which is well described by the term "spear-shaped;" and though the material is so widely distributed through the crystal, the total mass must be very small.

This mineral is not so hygroscopic as Jefferisite, and no difficulty was found in drying the material for analysis. When ignited, it exfoliates like other species of vermiculite, but not nearly to so great an extent as Jefferisite. After ignition it is decomposed by hydrochloric acid. The specific gravity of the green variety, mean of four determinations, 2.398; that of the yellow variety, mean of two determinations, 2.402. Before the blowpipe fuses with difficulty to a brown enamel. The following analyses were made by Mr. C. E. Munroe, Assistant in the Laboratory of Harvard College:—

Green Variety of Hallite.

	$\ddot{Si}$	$\dddot{Al}$	$\dddot{Fe}$	$\dot{Fe}$	$\dot{Mg}$	$\dot{K}$	$\dot{H}$	
(1)	35.97	7.61	8.83	1.13	31.34	0.43	14.32	= 99.63
(2)	35.80	7.29	8.73	1.13	31.56	0.49	14.33	= 99.33
(Mean.)	35.89	7.45	8.78	1.13	31.45	0.46	14.33	= 99.49
	19.14	3.47	2.63	0.25	12.58	0.08	12.74	
	19.14	6.10			12.91		12.74	
	3.	0.96			2.02		2.	
	3.	1.			2.		2.	

Yellow Variety of Hallite.

	$\ddot{Si}$	$\dddot{Al}$	$\dddot{Fe}$	$\dot{Fe}$	$\dot{Mg}$	$\dot{K}$	$\dot{H}$	
(1)	35.17	7.74	9.76	0.32	31.61	0.56	14.65	= 99.81
(2)	35.34	7.42	9.61	0.32	31.41	0.65	14.91	= 99.66
(Mean.)	35.26	7.58	9.68	0.32	31.51	0.61	14.78	= 99.74*
	18.81	3.53	2.90	0.10	12.60	0.10	13.14	
	18.81	6.43			12.80		13.14	
	3.	1.03			2.04		2.09	
	3.	1.			2.		2.	

$$R_{12}, \mathbf{R}_2 . O_{36} . Si_9 : 12 H_2O.$$

* Trace of manganese.

It will be seen from the above analyses that, although the atomic ratio between all the basic radicals and the silicon is the same as in Culsageeite, Jefferisite, and Biotite, the ratio between the protoxide and sesquioxide radicals is very different. In this respect the mineral resembles the phlogopite micas, in which also the protoxide radicals preponderate; and the symbol given above for Hallite, less the water, is identical with that given by Professor Dana as the more probable formula of the phlogopites.

The opacity produced by the interspersed material made it difficult to determine the optical characters of the mineral, as the rings produced with polarized light could only be seen with very thin plates, and the cross was therefore ill defined; so that, although in some cases there appeared to be a separation of the hyperbolas, the plates could not be distinguished from uniaxial. On one specimen the hexagonal form was very perfect, and the crystal presented the planes of a rhombohedron having an angle over the basal edge of about 122°, resembling the crystals of Biotite from Greenwood Furnace. Mr. Hall informs me that these more perfect crystals have only been found in one pocket of the serpentine.

The distinction, however, between the phlogopites and the biotites is not fundamental, either chemically or physically. Chemically, both species are orthosilicates; that is, the atomic ratio between the silicon and the sum of the basic radicals is 1 : 1. The species differ in composition only in the relative proportion of the sesquioxide and protoxide radicals. In the phlogopite the ratio of $\overset{\mathrm{II}}{R}$ to $\overset{\mathrm{VI}}{\mathbf{R}}$ is probably normally 2 : 1; but of the published analyses the value varies between that ratio and the ratio 3 : 2. In the biotites the same ratio is probably normally 1 : 1; but here, again, the different analyses which have been made give values varying between 5 : 3 and 1 : 2. In like manner the optical distinction between the phlogopites and biotites, of which so much has been made, is equally indefinite. Between a so-called phlogopite, like that from Jefferson County, N. Y., with an angle of about 15°, and the apparently uniaxial plates of biotite from Vesuvius, there is every possible gradation — sometimes, as I have shown, on one and the same mica plate; and I have endeavored in this paper to explain the cause of this variation. With the Vesuvian biotites themselves, — if the specimens in the mineralogical cabinet of Harvard College are fair representatives of the mineral from this locality, — it is only occasionally that we find a perfectly uniaxial plate. More commonly there are distinct evidences of twinning, and on the borders of the hexagonal plate may be dis-

covered a biaxial structure of which the optical plane is parallel to different edges of the hexagon on different parts of the plate.

It must, however, be remembered that, as by the process of twinning we have described the structure of the magnesian micas approaches that of uniaxial crystals, rhombohedral and other planes characteristic of the hexagonal system begin to appear on the crystal. This is illustrated not only by the crystals of Biotite from Vesuvius and from Greenwood Furnace, N. Y., but also by the more perfect crystals of Hallite from Chester County, Pa. In other words, *the process of twinning we have illustrated in this paper produces hexagonal crystals in external form as well as in optical characters;* and the question naturally arises, May not the hexagonal crystals of other minerals be formed in a similar way?—that is, may they not be developed from twinned molecules, which, though in their aggregate producing an hexagonal structure, singly would develop into biaxial crystals? Bearing on this point, we have discovered some very remarkable evidence.

We have in our possession a plate of Elba tourmaline cut perpendicular to the axis, in which the polarizing microscope shows on different zones a separation of the hyperbolas, which amounts in some positions to eight degrees; and in moving the plate across the field the optical divergence varies precisely as on plates of phlogopite and vermiculite. There is certainly no external evidence of lamination on tourmaline crystals, for the mineral is remarkably compact, and the crystals have not even a basal cleavage: but it will be remembered how readily some of the varieties pass by alteration into micas of the magnesian type; and this change to a foliated structure, in which the lamination is parallel to the base of the original hexagonal crystal, may be facilitated by a grouping of the molecules of the tourmaline, in the manner represented by Fig. 7.

We have also a plate of amethystine quartz, in which a beam of parallel polarized rays of light exhibits a twinning almost as symmetrical as that shown in Fig. 5,—the three zones being most beautifully mapped out by the alternating bands of right and left handed quartz, which are such a familiar phenomenon of these crystals; but, besides this, in each of these zones, near the border of the plate, can be distinguished a biaxial structure with an optical divergence of several degrees; and, on one other plate of amethyst we have had an opportunity of examining, we have also seen under the polarizing microscope the biaxial curves at one or more points.

These facts most distinctly suggest the theory that the optical phenomena of quartz are produced by a molecular structure similar to that

by which we have obtained identical phenomena in our artificial plates of mica, and that the two orders of crystals are aggregates of compound molecules, whose parts are twinned together in the one case in right-handed, and in the other in left-handed spirals, and, lastly, that the simple molecule, if developed normally, would produce a biaxial structure.* This theory is most markedly in harmony with the chemical relations of silica. The compound $Si\,O_2$ is the only one of the tetrad oxides which crystallizes in the hexagonal system; and ever since, by the study of the organic compounds of silicon, the quadrivalent character of the element has been made evident, this fact has been a striking anomaly in our chemical classification. Assume, however, that the molecule $Si\,O_2$ would develop normally into a rhombic structure, and that the hexagonal form of quartz is solely a result of molecular twinning, and the anomaly disappears. The molecule $Si\,O_2$ may be approximately of the same form as the molecule $Ti\,O_2$, in Brookite; but, having the exact dimensions and polar conditions which favor the mode of molecular twinning, described above and represented by Fig. 7, it may always develop into hexagonal shapes.

Are, then, all hexagonal forms thus closely related to the rhombic systems of crystals? And do all molecules of the dimensions and polar conditions illustrated by the figures of this article — that is, those which correspond to the rhomb of 60° and 120° — usually develop into hexagonal forms? May not the whole difference between an hexagonal and a rhombic form arise from a slight difference of dimensions, which determines a molecular macling in the one case, and a normal development of the single molecules in the other? These questions point out most interesting lines of investigation, and will recall to the mineralogist a number of facts bearing upon the subject. Allow me to refer to two of the most striking and most obvious.

On the crystals of chrysoberyl, the rhombic angle is 119° 46′; and every mineralogist is familiar with the hexagonal macling, similar

* Since the above was in type, we have received Am. Jour. Sci., IV., February, 1874, containing a description of the rhombic silica which Professor Maskelyne, of the British Museum, has discovered in the meteorite of Breitenbach. This new species of silica, which Professor Maskelyne calls Asmanite, has the form of a right rhombic prism, with an angle of 120° 20′, and the crystals are optically biaxial; but while the specific gravity of quartz is 2.6, that of Asmanite is said to be 2.245. It is perhaps to be expected that such a molecular macling as we have described would determine an increase of density, since thereby three molecules coalesce to form one; or it is possible that the remarks made in regard to calcite beyond apply also to quartz; but still the marked difference remains to be explained..

to Fig. 2, which is so very characteristic of this species.* Corundum differs chemically from chrysoberyl, in that a portion of the alumina in the former is replaced by glucina in the latter. Corundum has a perfect hexagonal form, and, fundamentally, may not the only crystallographic difference be that, in consequence of the replacement, a rhomb of 120° changes to a rhomb of 119° 46′? Now we have a plate of macled chrysoberyl, showing the normal wide divergence of the optical axes at certain points on its borders, and a nearly uniaxial structure at the centre, where there is an obvious interpenetration between the individuals of the macle, and where the superposition of the several laminæ is most beautifully shown by a polarized beam of parallel rays. We have also a section of a corundum crystal, presenting phenomena similar to those seen with the plate of tourmaline, described above. Further, we have observed like phenomena on a section of phenacite; and, although the last mineral contains silica, yet if the molecules of SiO_2 are crystallographically equivalent to those of Al_2O_3, it may be that the molecular structure both of phenacite and of beryl is more closely allied to that of chrysoberyl and corundum than the received theory of their chemical constitution would indicate.

We would not convey the impression that in all these crystals the appearances we have described are strongly marked, or that they have passed wholly unnoticed hitherto. Every one who has become familiar with the optical properties of crystals must have noticed that, with many always regarded as uniaxial, there is not unfrequently in some positions a small separation of the cross into the hyperbolas, which are characteristic of biaxial structure. But these irregularities, although long known, have never been satisfactorily explained. They have been hitherto residual features not accounted for by the received theory of crystalline structure, which explains so satisfactorily the general order of the phenomena observed with the polariscope. We have endeavored in this paper to trace their true significance: first, by showing that the appearances we are discussing are precisely similar to the effects which can be obtained by known means with mica plates; and, secondly, by observing on different specimens of various minerals every intermediate stage between the unmistakable effects of twinning on plates of mica or vermiculite, and the delicate phases of the same phenomena, seen with sections of crystals of tourmaline, corundum, or phenacite. One other illustration of our theory.

* See also Dana's System of Min., 5th ed., Figs. 154, 155, p. 156.

The rhombic angle of witherite (native baric carbonate) is 118° 30′, and the all but universal hexagonal macling of crystals of this species is a well-known fact.* The rhombic angle of aragonite (the corresponding form of calcic carbonate) is 116° 10′, and the much greater divergence of this angle from 120° determines, as is also known, a style of macling which is usually quite different from that of witherite. In the isomeric calcite, however, we have the type of all hexagonal forms. Hitherto the crystalline forms of calcite and aragonite have been regarded as being as widely separated as possible, and a comparison of these two well-known mineral species has furnished one of the most striking illustrations of demorphism. But may not, after all, the comparatively small physical differences between these two minerals correspond to a crystallographic difference no greater, fundamentally, than the difference between the rhomb of 116° 10′ and the rhomb of 120° ?

The macles of chrysoberyl and witherite are illustration of a general truth, fully recognized in mineralogy, that all rhombic crystals, whose angles approach 120°, tend to form hexagonal macles. The optical phenomena described in this paper certainly suggest the theory that a perfect hexagonal form and structure may be the result of a more fundamental and molecular macling, which results when the angle is exactly 120°.

Observations of Senarmont.—The only previous observations which we have been able to find bearing on the subject of this paper are those of the late eminent mineralogist, H. de Senarmont, of Paris. In a well-known paper (Ann. Chim. et Phys. 3e xxxiii. 391), Senarmont showed that salts which were both geometrically and chemically isomorphous might have very different optical relations; for example, that, while the biaxial crystals of two such salts might have the same bisectrix, the plane of the optical axes in the crystals of one might be perpendicular to the corresponding plane in those of the other. He further proved, by crystallizing together two salts so related, that in the crystals of the isomorphous mixtures thus obtained the optical angle varied with the varying proportions of the constituents, between the extreme conditions in the crystals of either salt; and by trial he succeeded in forming from two biaxial salts crystals which, in monochromatic light at least, appeared uniaxial. In a later paper (Ann. Chim. et Phys. 3e xxxiv. 171), Senarmont applied the principles, which he had thus experimentally verified, to explain the variation of the optical angle of the micas. In this paper he seeks to prove, first,

* See figures, Dana's System of Min., p. 697.

that all micas may be referred to a right rhombic prism with angles of approximately 60° and 120°; secondly, that, while in some micas the plane of the optical axes is parallel to the shorter diagonal of the rhomb, as in Fig. 8, in others it is parallel to the longer diagonal, as in Fig. 9. Interpreting these facts by the results of his experiments on isomorphous salts, he draws the inference that there are, crystallographically at least, but two species of mica which are geometrically isomorphous but optically distinct, that these are represented by the varieties which have the widest optical angle between the axes in either plane, and that all other varieties with optical angles varying from 0° to 70° in either direction are isomorphous mixtures of the two optically distinct conditions of the mineral.

Fig. 8.

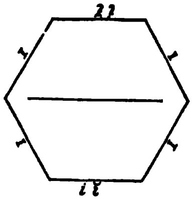
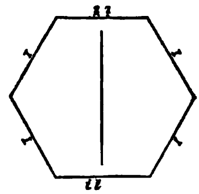


Fig. 9.



The observations described in this paper, although they prove that another cause may also determine the variation of optical angle in micaceous minerals, do not necessarily invalidate this beautiful theory of Senarmont. The variations observed with other minerals, not only on different specimens, but with the same specimen at different temperatures, and which are so beautiful seen with the orthoclase from Wehr in the Eifel, and with crystals of selenite, indicate that such variations may be determined by conditions of molecular structure wholly independent of the macling here described. We have shown that the macling does produce the variation in certain cases, and it must remain for future investigation to assign the limits of the influence which this cause may exert. We would only remark in conclusion that, although in the 57 varieties of micas examined by Senarmont he did not note a single instance in which the position of the plane of the optical axes — with reference to the diagonal of the rhomb — was different on different parts of the same specimen, or even on different specimens from the same locality, he does describe and figure several remarkable macles of muscovite mica similar to those of vermiculite described above and represented by Fig. 5. In one instance the plane of the optical axes is parallel to the shorter, and in the other to the longer diagonal of the rhombic prism; but in both cases it has the same relative position in the several individuals of the macles, the three planes forming with each other angles of 60°. On the plate of another macle a difference of optical angle was observed on different portions of the plate, and this effect was probably similar to that we

have been studying in this paper. On another plate, from the same crystals he observed a superposition of the laminæ of the different individuals of the macle; and the following language by which this phenomena is described, and which is the only reference made to it, shows how closely he came to the results recorded in this paper: —

"Une partie seulement du cristal maclé est commune aux trois lames; mais ici certaines plages (pointillées sur la figure) ont un caractère optique tout particulier; elles ne cessent jamais de développer des couleurs dans la lumière polarisée, quelle que soit d'ailleurs l'orientation de la lame cristallisée. Il est évident que dans ces plages il y a superposition de lames appartenant à des cristaux orientés, les uns comme le petit, les autres comme le grand cristal, de façon que quand les unes ont leurs sections principales dans le plan de polarisation, les sections principales des autres font avec ce plan des angles de 60 degrés.

"Cet exemple prouve donc, non-seulement que les micas peuvent se grouper latéralement sans que leurs clivages cessent d'être parallèles, mais que des feuillets superposés peuvent même appartenir à des cristaux dont l'orientation diffère de 60 degrés. Un pareil mode de groupement, qui ne trouble ni la régularité de la cristallisation, ni la transparence, semble indiquer que l'arrangement moléculaire de ces prismes rhomboïdaux diffère très-peu de celui qui conviendrait au prisme hexagonal régulier."

IV.

AN ASEXUAL GROWTH FROM THE PROTHALLUS OF PTERIS SERRULATA.

By William G. Farlow, M.D.

Read, Jan. 28, 1874.

While studying the development of the archegonium in the Polypodiaceæ, a few weeks ago, in the botanical laboratory of the University of Strasburg, a peculiarity was first noticed in the prothallus of Pteris serrulata which seems to have an important bearing on the question of the fern prothallus in general.

The material used was taken from a pot in which Pteris serrulata and Aspidium molle had been sown. At the beginning of the investigation there were a number of seedlings of both the above-named species which were considerably advanced in growth; and in addition there were numerous prothalli, from some of which young plants had begun to grow, and others still younger on which no incipient plantlets could be discovered with the naked eye. A search was made among the latter for prothalli in a condition suitable to demonstrate the earliest stages of growth after the fertilization of the archegonium. Some of these prothalli were normally developed, having both antheridia and archegonia, from which occasionally an embryonal growth was seen. During the search, however, numerous specimens were found presenting the anomaly of scalariform ducts in the substance of the prothallus; and such prothalli, when still further developed, showed that the young fern-plantlets produced by them were the result of a direct budding of the cells, and not of the changes caused by the act of fertilization in a single embryonal cell. The number of cases in which the above-mentioned peculiarity was manifested was about fifty; but, undoubtedly, the actual number was greater, inasmuch as some of the young fern-plantlets in the pot, which were too old to allow one to say whether they were of the regularly developed (that is, by growth of an embryo) or not, probably belonged to the number of those developed by direct budding. The shape of the prothalli was, as usual, more or less obcordate; and those in which the anomaly presented itself, although variable in outline, were narrower than the

others. This narrowness may have been only accidental and the result of crowding in the pot, as very often happens in the cultivation of ferns. In a single case, Fig. 13, one side was developed into a sort of secondary prothallus. The cells of the prothalli were perhaps somewhat paler than usual; and those which, near the concavity of the heart, are generally more numerous than in other portions and isodiametrical, were here much longer than broad, — that is, longer in the direction from the centre of the prothallus towards the concavity. As is well known, fern prothalli are generally heart or kidney-shaped, and the two sides composed of a single layer of polygonal cells, the centre of a portion decidedly thicker and consisting of several layers, which we may call the cushion; and in this last-named portion are situated the archegonia, while the antheridia are much more widely dispersed, being found also in the lateral lobes. As before said, the most striking feature of the abnormal prothalli was the presence of a dotted duct in the cushion a short distance back of the concavity, just where the archegonia are generally found. But wherever such scalariform vessels were present there were no traces whatever of archegonia to be found, although antheridia were always abundant, as well as the hairs, which here fulfil the offices of roots. See Figs. 1, 6, and 9, in which *a* shows the position of the scalariform ducts. As may be seen from Figs. 6 and 9, the scalariform ducts arise singly, and are situated in the central portion of the prothallus. They scarcely differ in shape at first from the adjoining cells, which are longer and relatively narrower than the superficial cells. The ducts increase by division in a direction parallel to the surface, so that, in a longitudinal section, we find several lying one above the other.

Another peculiarity often, but not always, accompanying the presence of scalariform ducts, was the formation of a process or outgrowth in the concavity of the thallus, as shown in Figs. 1, 6, and 12. This outgrowth was variable in length, often being short and imbedded between the lateral lobes, but sometimes projecting as a narrow tapering process. In one case, it was forked at the extremity. The growth by means of a single terminal cell is shown in Fig. 8. As just mentioned, the existence of a process in the concavity is a striking peculiarity, but not quite a constant occurrence, as is the presence of scalariform ducts. The first scalariform duct arises in the prothallus, as I have just remarked; and soon appear others, always in a line between the original duct and the nearest point of the concavity. In this way arises an interrupted row of ducts, which may extend, when a process is present, nearly to its extremity. The cells surrounding the original vessel

soon assume the form of vessels themselves, and thus a rudimentary bundle is formed. It happens rarely that two such scalariform ducts appear simultaneously in parts of the prothallus remote from one another. I only saw one such case, Fig. 13, *a* and *b*.

It now becomes necessary to consider the relation of the scalariform ducts to the other cells of the prothallus, and this must be done by making longitudinal and transverse sections of the region in which the ducts lie. We have such longitudinal sections in Figs. 2 and 7, of which Figs. 1 and 6 give a view from above, but much less magnified. From these sections we see that the prothallus forms a compact tissue in which certain cells have assumed the character of scalariform ducts, while the others remain unchanged. From no section made was I able to see any trace of an archegonium. In two instances, when seen from above, a combination of four cells led me to suppose that there was some signification to be attached to this arrangement. Fig. 5 is a magnified view of Fig. 1, in which this arrangement in four occurs; but, as Fig. 4, a longitudinal section, shows no connection between the four surface cells and the scalariform ducts, I am compelled to regard the two cases mentioned as having only accidentally such a superficial cell-conformation.

So far the changes mentioned have taken place in the plane of the prothallus itself. Now a change occurs which produces a growth in a direction perpendicular to the prothallus, and this growth is easily distinguished from the usual embryo growth. A swelling is seen, generally on the under surface of the prothallus, shortly after the appearance of the scalariform duct. This swelling is situated on or very near the line connecting the original duct and the nearest point of the concavity. When there is a process, this swelling very often appears near its extremity, as in Fig. 6, *b*. When two such swellings appear simultaneously, they are generally situated side by side. In all cases, there is seen back of the swelling the scalariform duct or ducts lying in the substance of the prothallus itself. It is impossible for me to say in which cells of the prothallus this swelling or outgrowth originates. Longitudinal sections, as in Fig. 7, *a*, show no change by which the cells of the outgrowing portion — which is, in this case, on the upper instead of the lower surface of the prothallus, as is more commonly the case — can be distinguished from the cells which are to remain a portion of the prothallus. From the not unfrequent appearance of a bursting through the surface, it can perhaps be inferred that the superficial cells take no part in the growth. Certainly no particular cell or cells seem to be the place of origin of the new growth, but it seems to be a

direct continuation of the prothallus cells, and not a distinct organization temporarily attached to it, as is the case with an embryo growth. This swelling, to which I have intentionally avoided giving the name of bud, develops and shows all the characteristics of a fern leaf, and is, in fact, not a stem, but a true leaf. When it arises on the under surface of the prothallus, this leaf grows forwards, curves round the border of the concavity, and raises itself into the air. When two such swellings occur by the side of one another, one generally grows from the upper, the other from the under surface of the prothallus, as in Fig. 10. In the mean while, there appears on the basis of the leaf, or on what is now so far differentiated that it is evidently the leaf-stalk, a bud, which very soon can, by means of the cell-cap on its end, be recognized as a root. This grows always in a direction the reverse of the leaf; that is, backwards away from the concavity. After the appearance of the root, a bud appears on the basis of the leaf-stalk, looking towards the concavity, and from this grows the stem. As a rule, the leaf is tolerably far advanced in its development before the root appears, and the root invariably precedes the stem-bud. The terms forward and backward with relation to the concavity of the prothallus are, of course, inapplicable when the young plantlet is formed at or near the end of a process of the character above described, when the leaf and root shoot out *ad libitum*. In all cases a vascular bundle traverses the leaf and root, and these are in connection with the vascular bundle of the prothallus.

If now we compare Figs. 11 and 14, we shall clearly see that the cases we have been discussing differ widely from the ordinary cases of embryonal growth. Fig. 11 represents a longitudinal section through the spot where a young plantlet, such as we have described, shoots out from the prothallus (p, $p_,$), b represents the leaf, r the root, and s the stem-bud, which was cut a little to one side of the median line. Fig. 14, taken from Sachs's Lehrbuch der Botanik, represents a longitudinal section of a prothallus and a normally developed embryo attached, the whole not so strongly magnified as Fig. 11. First, at a glance, 14 differs from 11 in the fact that the young plant in the latter case is so intimately connected with the prothallus that one cannot decide where the one begins and the other ends; while, in the former, it is perfectly easy to trace the outline of the young fern. Secondly, we have in 14 a structure known as the foot, f, by which the developing fern is separated from the prothallus,—a structure of which we find no equivalent in 11. Thirdly, the vascular bundle of the plantlet is in direct connection with vessels which lie wholly in the prothallus.

Fourthly, the order of evolution is different in the two cases. In 11, the leaf arose first, as we saw, and was tolerably well developed before a root and afterwards a stem-bud made their appearance. In 14 the root anticipates by far both the leaf and stem-bud in its development; and, in fact, the root and stem are not produced from the leaf-stalk, but (and this fact is not to be learned from the figure, but from the accompanying description in Sachs) by the subdivision of a single cell into four, one of which forms the foot.

So far as I know, a budding similar to that in the cases described is only mentioned by Wigand, "Botanische Zeitung," Feb. 16, 1849, and by him in language which, it must be confessed, is not a little obscure: "Eine beachtenswerthe Erscheinung begegnete mir bei einigen Exemplaren, nämlich eine *Sprossenbildung*, ungefähr an der Stelle des Lagers wo das beblätterte Pflänzchen angelegt wird, entspringen junge *Vorkeime* von derselben Gestalt, wie die Hauptvorkeime im jungen Zustande, mit dem verschmälerten Ende (dem Sporenende entsprechend), an dem Lager festsitzend, später sich loslösend und wie ein selbständiger Vorkeim sich verhaltend." From the above paragraph, it would be, perhaps, difficult to say whether Wigand had seen any thing similar to our case. But, taken in connection with his Tafel 1, Fig. 25, where a process in the concavity is clearly seen, it seems probable that he had seen a growth which did not proceed from a fertilized archegonium.

The bearing of the facts already enumerated upon the question of the function of the fern-prothallus is very important. Since the publication by Leszcyc-Suminski, in 1848, of his observations concerning the sexuality of ferns, the prothallus has been regarded as an organ intermediary between the spore and the fully developed plant, growing out of the former, and bearing sexual organs which by mutual co-operation produce the latter. It has been considered impossible for a spore to produce a fern-plant directly without the intervention of a sexual union. But, from the cases we have been considering, it is evident that this process is not absolutely necessary, since we have seen that a young-fern can be produced from the spore by a purely vegetative or budding process, — a process as clearly unsexual as, for instance, the production of plantlets on the fronds of Asplenium viviparum. This fact is an unexpected one for those who constantly see unity and simplicity in nature. Although in by far the majority of cases the prothallus does bear archegonia whose embryos develop into ferns, the monstrosity, if so we please to call the present cases, having once been noticed, may of course be expected to occur at any time; and, now that the attention of botanists has been called to it, it may prove not to be rare. As, in the present

instance, certain examples bore archegonia with embryonal outgrowth, and others only direct bud-development, it is of course interesting to know whether the young plantlets of the two kinds of origin exactly resemble one another in their after development. For this purpose, a number of specimens evidently belonging to the category of abnormal growths were transplanted into a pot where their growth could be watched. So far there is no difference between their growth and that of plantlets developed from embryos.

In conclusion, I would take this opportunity to thank Professor De Bary of Strasburg for material and advice kindly afforded during the course of the foregoing investigations.

EXPLANATION OF THE FIGURES.

Figs. 1, 6, 9, 12, 13. Different forms of prothalli of Pteris serrulata, slightly magnified. In all, *a* represents the original scalariform duct; *b* the first leaf; *r* root; and *s* the stem-bud. In 12, *b'*, *r'*, *s'*, represent the corresponding parts of a second plantlet. In all, the position of the root-hairs and archegonia are seen in the lower part of the prothallus.

Fig. 2. A longitudinal section of fig. 1.

Fig. 3. View of a terminal growing cell of the same seen from above.

Fig. 4. Section parallel with *x*, fig. 3, and more highly magnified.

Fig. 5. A portion of fig. 1 seen from above; *a* original scalariform duct; *x* signifies the same cells as in 2 and 4.

Fig. 7. Longitudinal section of fig. 6, in which *a* represents the upward-growing portion. Several antheridia are seen at one end.

Fig. 8. Portion of a young prothallus, showing the growth in the concavity and scalariform ducts in two groups.

Fig. 10. Magnified view of fig. 9, showing the origins of two leaves and the ducts lying behind in the prothallus.

Fig. 11. Longitudinal section through the place of origin of a young plantlet produced by direct budding: *b* leaf, *r* root, *s* stem-bud, *p,p*, prothallus.

Fig. 14. A corresponding section of a normally fertilized prothallus and plantlet, copied from Sachs's Lehrbuch der Botanik: *p,p*, prothallus, *f* foot, *d,d*, vascular bundle, *b* leaf, *r* root.

Correction.— For PTERIS SERRULATA, in the title and elsewhere, read PTERIS CRETICA. The subsequent development of the plantlets has proved the latter to be the species to which the prothalli belonged.— W. G. F.

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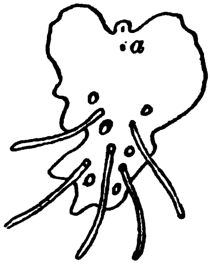

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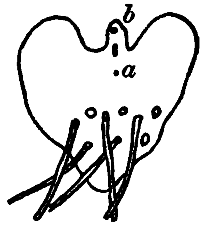

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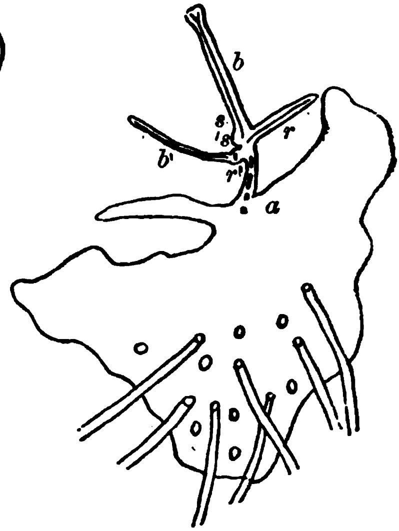

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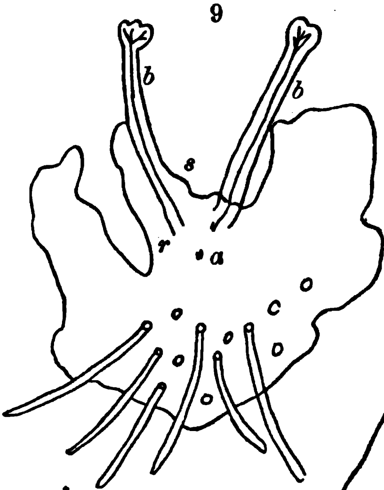

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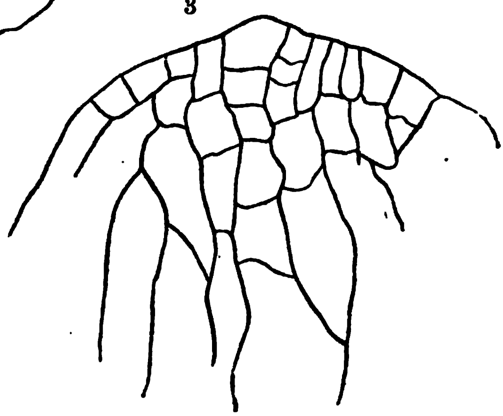

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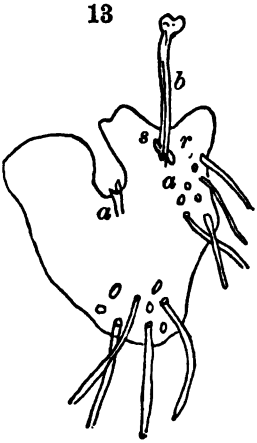

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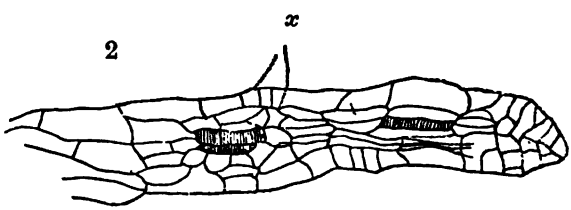

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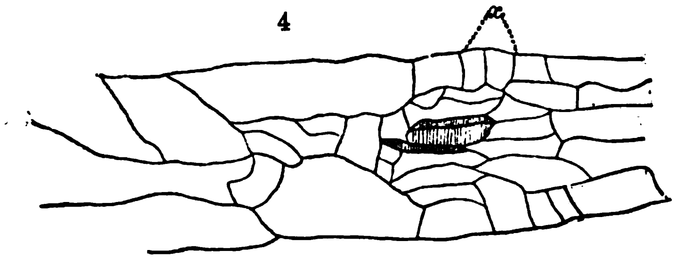

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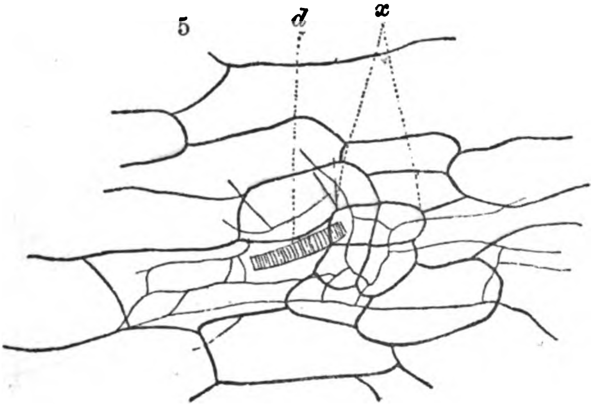

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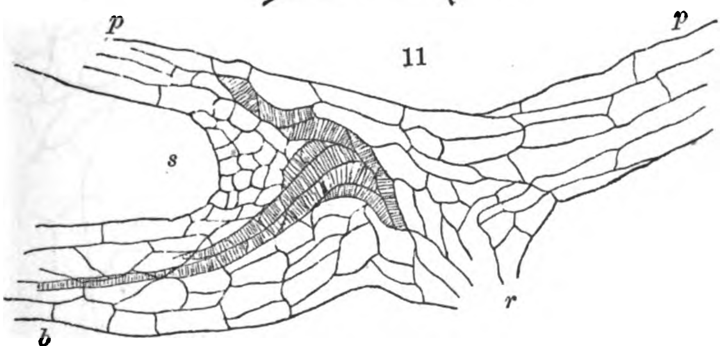

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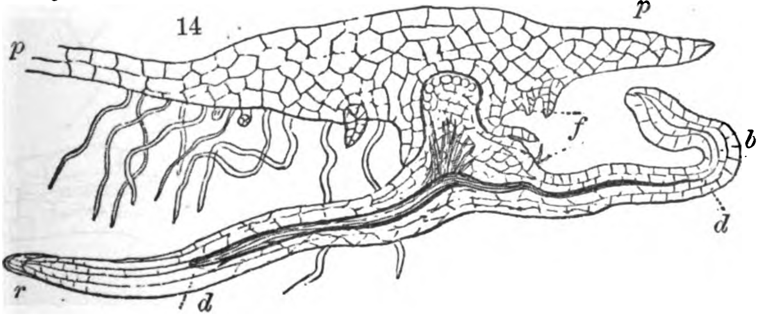

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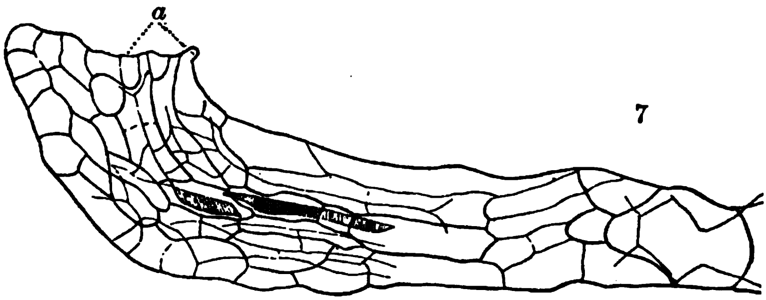

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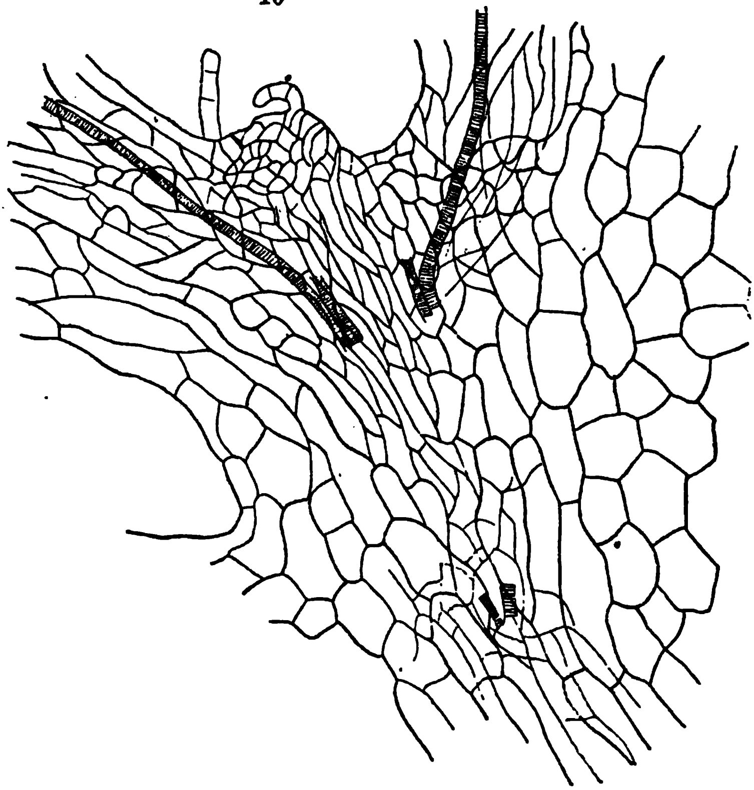

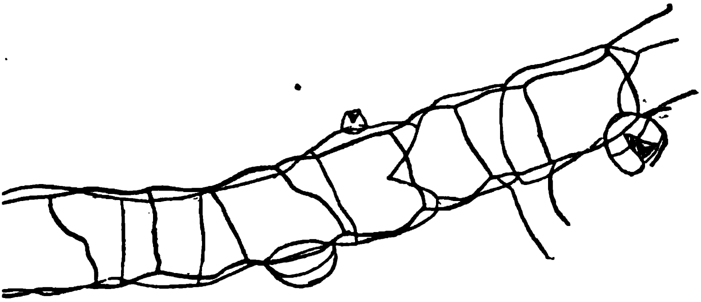

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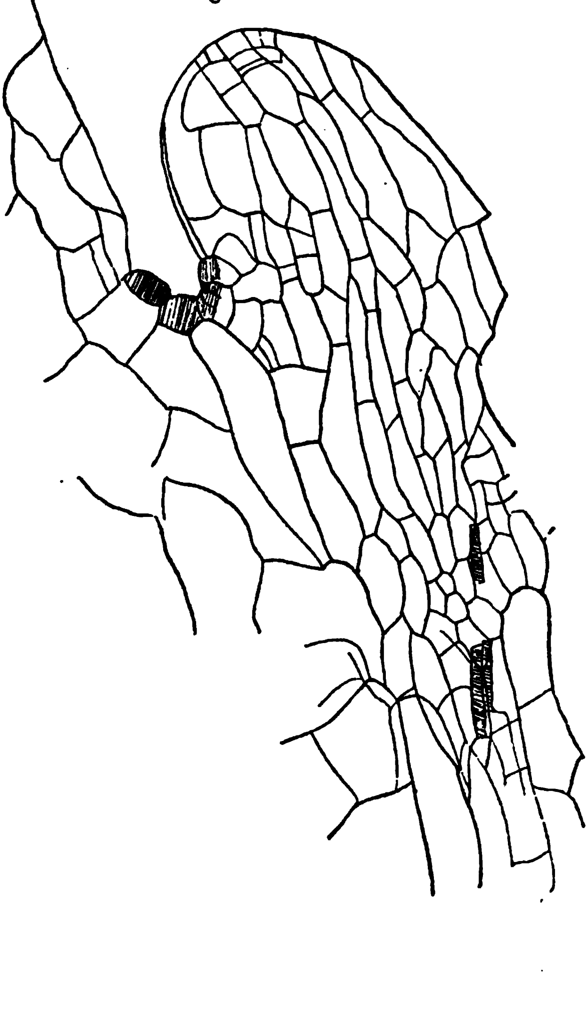

V.

ON A PRACTICAL TEST OF THE CONDITION AND COMPOSITION OF NATURAL WATERS.

By Aug. A. Hayes, M.D.

Read, April 14, 1874.

Early in the winter of 1860 I made a verbal communication to the Academy on a mode I had devised for testing the composition and characters of waters at rest or in motion. The illustrations were drawn from the then condition of Mystic Pond, as a source of supply of potable water to the city of Charlestown.

The somewhat novel condition of the pond led me to ask for more time in continuing observations on one source of the water; and, as extensive changes of flow would result from the works to be constructed, it was foreseen that some years must elapse before replies to one or two questions arising could be given.

At that time I stated that the earlier analyses of the water made by myself and others showed that the water at the bottom contained the salts and compounds of sea-water; while a considerable depth of the surface water was adapted, through ordinary purity, as a source of supply, while flowing as a stream.

The saline water at the bottom might be the infiltration from sea-water at a higher level, or possibly an overflow at times of high water, which the dam did not prevent. The source of this water could be determined after the construction of the new works, and subsequent observations and analyses.

It is a frequent remark that ponds and lakes are but enlargements and broadenings of rivers; but there are few cases only of its truthfulness of application. Here we had streams of quite pure water poured into a basin, the bottom of which contained saline water, unfit for domestic purposes.

The success of the public works to be erected for the supply of potable water was deemed by the commissioners and engineer as dependent on a suppression of the contaminating water, and the continuous flow of purer water above it. Further doubt was involved in the solution of the question, arising from the cooling of the surface in the

change of seasons to the maximum density, when displacement occurs to the depth where density, due to contamination, equals density arising from cooling.

A moment's consideration of the law of diffusion in liquids at rest will convince any one of the great importance which must be given to the act of flowing, through which it is possible to have a comparatively pure water as a supply, over a body of quiescent water in repose of other composition.

While the subject of source of supply was under consideration, an opportunity existed for exact observations on the volume and position of this mass of contaminated water, more sure than the results of analyses of samples from different depths.

Recurring to my observations on sea-water, I suggested to Mr. C. L. Stevenson, acting as engineer to the Board of Commissioners, that a copper wire, or a strip of silvered copper, weighted so as to descend into the silt, and buoyed at the surface in a vertical position, would take a polarized state. The lower portion would be in the condition of zinc in a compound arc of zinc and copper in acid, being acted on by the sulphur eliminated from a sulphur compound present. In this way the wire, or strip, would write a true statement on itself of the depth of the contaminated water at any point, and define exactly where contamination ceased, by a bright continuous surface above this line, after some days of immersion.

Mr. Stevenson entered with zeal and care on the application of this then novel test, not only demonstrating the condition of gradations of impurity below, but defining by the definite line on the wire, or strip, the exact depth of the purer water above. Many observations were made, resulting in proving the adequacy and value of this mode of testing a mass of water for variation of composition in its parts.

The following year Mr. Stevenson and his assistants extended, agreeably to his promise, the application of the method of observing to other bodies of water, and gave me his original notes of results, both positive and negative: positive in relation to the detection of the smallest portion of contaminated water, and negative when pure natural water alone existed.

Many modifications of the original applications were made, with instructive results observed. Among these results was the considerable conducting power of a hemp or long flax string, which enabled it to replace in part of the length the copper wire or copper-silvered band. He found that the chemical action, when the testing line was used with the whole copper wire, or parts of it, the ferric cyanide of

the greenish, blue-colored twine, was decomposed in that part of the water naturally pure, while in the foul water the original color was retained. This change was due to the local production of alkalinity on that part of the twine in the purer water, as a consequence of its polar state, resembling that of a metal wire.

In an extreme case the copper wire, immersed in the silt at the bottom of the water, actually presented scales of sulphide of copper, formed after forty-eight hours' immersion, the temperature 62½° F.

These points illustrate the generality of application in the method, and lead me to notice particularly the chemical action on which it depends, as a mistake has already been published.

When in the decomposition of decaying matters the stage is reached permitting the escape of sulphide of hydrogen, the ordinary tests of lead, silver, and copper compounds detect the sulphur in the ordinary simple way, or the odor of this gas indicates its presence. We have entirely different conditions under view when this test is applied. The most sensitive test for free sulphur fails to detect its presence. A compound of feeble stability, liable to change under the simple change of temperature, or advance in fermentative action, is to be sought for as a deleterious substance. The means used in ordinary cases fail utterly; but the electrical disturbance induced in a copper wire by a simple difference of one part of its length immersed in one medium, while the other part is wet by a slightly differing medium, is sufficient to develop locally,—and locally only,—a change enabling us to obtain evidence of the existence of the deleterious compound, by withdrawing its sulphur, or other like element. The sulphur detected in this way is presumably that which would act under natural conditions offensively or noxiously.

Since the varied application of this method to natural waters has been extended, I have applied it successfully to detect sewage, when mixed with or impregnating drainage water and well water.

The method has been applied to the small volumes of water taken in laboratory analyses, with the same good results. It is only necessary to preserve a separation of the pure from the impure water, through both of which the bright copper wire passes, the temperature of 62° to 75° F. being kept constant. The impure water may be made denser by common salt, so as to take the lowest place; while in testing the method I have made the impure water rest above a pure solution of salt, with like results.

The subject of the contamination of streams and other sources of supply, on which whole populations depend, is becoming of grave im-

portance in this country, and the most minute inquiries in this direction are full of interest.

After the exclusion of high tides from Mystic Pond, analyses prove the continued presence of an undue amount of sea-water constituents in the greatest depths. From obvious sources, dissolved organic compounds are daily added to the water; and, if the purity of this important supply of water is to be preserved, both restrictive measures and careful engineering devices will be required.

The details of observations made on this water would extend this paper to great length. Belonging to the chemical history of waters, they have more of an economical than strictly scientific importance; and this remark applies to the observations made in other bodies of water.

VI.

A REVISION OF THE NORTH AMERICAN CHENOPODIACEÆ.

By Sereno Watson.

Read, April 14, 1874.

The classification of the *Chenopodiaceæ* given by Moquin-Tandon in De Candolle's "Prodromus" twenty-five years ago has been ever since substantially accepted and followed, although several of his genera have not been sustained. In the present study of the North American genera, it has seemed best to deviate in some measure from his arrangement, partly to make the sequence more natural, in part because the distinctions upon which his divisions are founded do not hold good in the cases under consideration.

The great variations that occur in the floral envelopes in this order are worthy, from their bearing upon physiological questions, of a more careful study than has been given to them. Staminate flowers, whereever they occur, excepting a single genus, are accompanied by the normal calyx, regularly 4–5-cleft or -parted, and never in any way conspicuously appendaged. In perfect flowers, likewise, a calyx is always present, but with the number of the sepals not unfrequently reduced, very rarely bracteate or obscurely bracteolate, remaining unchanged in fruit or slightly enlarged, or the lobes becoming thickened or costate, or developing a thin horizontal wing. When the flowers become exceptionally pistillate, the calyx remains the same in character; but in the proper monœcious and diœcious genera the flowers are decidedly dimorphous, the pistillate being for the most part wholly without calyx and enclosed within bracts. These bracts assume very diverse forms and peculiarities, though their foliaceous character is generally evident, at least in the flower. The wings, when present, corresponding to the margins of the compressed bracts, are always vertical, as are also the dorsal crests. In *Grayia* and *Eurotia* (and *Ceratocarpus*), in which the bracts are obcompressed, the winged marginal nerve in *Grayia*

and the horned or awned costas of the latter correspond to the mid-nerves of the bracts.

This bracteate division (the *Atripliceæ*) is connected with the *Chenopodieæ* by the genera *Blitum* and *Monolepis*, with their often fleshy sepals reduced in number, and especially by *M. chenopodioides*, in which the solitary so-called sepal is evidently foliaceous. Some of the species of *Atriplex* show a still closer connection, as *A. hortensis* and others of the section *Dichospermum*, in which the fruit may upon the same plant be either horizontal and included within a normal calyx, or vertical and compressed between broad foliaceous bracts, but wholly without calyx. Other species have within the bracts, occasionally or constantly, a more or less regular calyx of several well-developed sepals. On the other hand, in *A. Gmelini* fertile flowers are sometimes found without either bracts or calyx.

The position of the seed as vertical or horizontal is mainly determined throughout the order by the nature of the calyx, being horizontal whenever the calyx is regular and appressed to the fruit, and for the most part vertical if it be either absent, or loose and urceolate or tubular, or reduced to fewer than the usual number of sepals. The character of the seed-integument (simple or double), upon which the *Eurotieæ* and *Camphoraceæ* are separated from the *Chenopodieæ*, has less value than Moquin gave to it, as is apparent in the *Salicorneæ* and *Suædeæ*. Among the North American genera, the only one (*Kochia*) referred by Moquin to the *Camphoraceæ* has evidently a double testa.

A nectary or disk very rarely occurs in either male or female flowers. In *Sarcobatus* only, which is in several respects a remarkable genus, do they become conspicuous. The pistillate flower has here a calyx and develops a horizontal wing similar to that of *Salsola;* but the inner portion of the envelope is in other respects very different and peculiar, and must probably be considered an expansion of a perigynous disk enclosing the membranous ovary. The male flower is even more anomalous, having neither calyx nor bracts, but a central peltate scale about which the stamens are arranged, and which appears to be an extraordinary development of a central nectary.

Synopsis of Genera.

Suborder I. SPIROLOBEÆ. Embryo spiral. Seed-integument double albumen none or scanty. Saline herbs or shrubs, with fleshy linear leaves the stems not jointed.

* Embryo conical-spiral.

1. Salsola. Flowers perfect, axillary, 2-bracted; calyx 4–5-parted, transversely winged in fruit: seed horizontal, with a membranous testa.

** Embryo flat-spiral.

2. Sarcobatus. Flowers monœcious or diœcious, dimorphous, without bracts, the staminate in aments, the pistillate axillary and solitary; fruiting calyx a coriaceous sac, transversely winged: seed vertical, with a membranous testa.

3. Suæda. Flowers mostly perfect, axillary, with small bractlets; calyx 5-cleft or -parted, rarely crested or somewhat winged in fruit: seed horizontal or vertical, the testa crustaceous.

Suborder II. CYCLOLOBEÆ. Embryo annular.

Tribe I. Chenopodieæ. Flowers usually perfect, not dimorphous, bractless, the calyx persistent. Seed-integument double: albumen mostly copious. Stems not jointed nor the leaves fleshy.

* Seed horizontal. — Beteæ.

4. Aphanisma. Calyx 3-fid, not becoming costate nor winged, persistent at the base of the capsular fruit; flowers minute, monandrous, axillary.

5. Teloxys. Calyx 5-parted, subcarinate, partially enveloping the smooth fruit; flowers monandrous or pistillate, axillary and solitary, in repeatedly dichotomous cymes.

6. Cycloloma. Calyx 5-cleft, becoming transversely winged, closely enveloping the pubescent fruit; flowers axillary and solitary, in spreading panicles.

7. Kochia. Calyx 5-cleft, persistent over the fruit, usually transversely winged; flowers solitary or few in the axils, spicate: leaves linear-terete: albumen scanty.

8. Chenopodium. Calyx 5- or 2–3-cleft or -parted, at length subcarinate or subcristately costate, enclosing the fruit; flowers clustered in panicled spikes. (Seeds often vertical in § *Botryois*.)

** Seeds mostly vertical. — Bliteæ.

9. Roubieva. Calyx 3–5-toothed, becoming saccate with a contracted apex, nerved and reticulated; flowers solitary or few in the axils: leaves pinnatifid.

10. Blitum. Flowers perfect or pistillate; calyx 3–5-cleft, not appendaged, often fleshy, partially enclosing the fruit: stamens 1–5.

11. Monolepis. Flowers polygamous; calyx of a single bractlike sepal, not appendaged: stamen 1: fruit naked.

Tribe II. Atripliceæ (including *Eurotieæ*). Flowers monœcious or diœcious, dimorphous; staminate flowers with a calyx, bractless; pistillate flowers very rarely with a calyx, usually enclosed in two more or less united bracts. Seed vertical, with copious albumen. Stems not jointed, nor leaves fleshy.

* Bracts compressed, free or more or less united: testa double.

12. Atriplex. Fruiting bracts with the margins often dilated and the sides often appendaged: radicle inferior to superior.

** Bracts obcompressed, united, not appendaged: testa simple: radicle inferior.

13. Eurotia. Fruit-envelope somewhat obcompressed, conical, not winged, very densely hairy-tufted, 2-beaked.

14. Gratia. Fruit-envelope strongly obcompressed, orbicular, longitudinally wing-margined, smooth, colored.

Tribe III. Corispermeæ. Flowers perfect, not dimorphous, bractless. Calyx 1–3-sepaled, hyaline, marcescent. Seed compressed, vertical, with closely adherent pericarp: albumen copious. Stems not jointed and leaves not fleshy.

15. Corispermum. Fruit elliptic, not muricate, acutely margined: flowers solitary, axillary.

Tribe IV. Salicornieæ. Flowers mostly perfect, not dimorphous, bractless, arranged by threes in close spikes. Stamens 1–2. Fleshy saline plants, with jointed stems and scalelike leaves.

16. Salicornia. Flower-clusters decussately opposite, sunk in the rachis of the spike; calyx saccate, fleshy, coherent to the rachis, becoming spongy: albumen very small: branches opposite.

17. Spirostachys. Flower-clusters spirally arranged; calyx 4–5-cleft, the sepals carinate: albumen rather copious: branches alternate.

1. SALSOLA, Linn.

Flowers perfect, 2-bracted. Calyx 5- (rarely 4-) sepaled, at length horizontally 5-winged, enclosing the fruit. Stamens 5–3. Ovary depressed-globose: style slender, with 2 linear stigmas, persistent. Fruit a membranous utricle, loosely enveloping the horizontal subglobose seed. Testa membranous: albumen none. — Saline plants with fleshy sessile subcylindrical leaves and axillary sessile solitary flowers.

1. S. Kali, Linn. Annual, herbaceous, erect or decumbent, ½–2 feet high, diffusely branched, smooth or often roughly hispid; leaves alternate, ½–1 inch long, semi-terete, amplexicaul, spinosely tipped, the floral leaves ovate-lanceolate to ovate, with a broad base, strongly nerved and spinose, and with the scarious margin often hispid-ciliate; bracts similar, somewhat smaller and unequal; fruiting calyx turbinate, truncate, the scarious sepals imbricated and connivent above into a short beak; wings pinkish, veined, orbicular, 3–4 lines broad. — Seashore from New England to Georgia. The smoother form, with the bracts and floral leaves naked, is the *S. Caroliniana* of Walter. The integument of the seed is plainly double.

Salsola Kali, Linn. Pursh, 197. Torrey, Flora U. S. 297; Flora N. Y. 2. 142. Beck, Bot. 298. Chapman, 378. Gray, Manual, 411.

Salsola Caroliniana. Walter, Fl. Car. 111. Michaux, Flora, 1. 174. Lam. Dict. 7. 295. Elliott, 1. 331. Röm. & Schult. Syst. 6. 229. Spreng. Syst. 1. 925. Bigelow, Fl. Bost. 106. Dietrich, Syn. 2. 997.

Salsola Kali, var. *Caroliniana*. Nuttall, Genera, 1. 199. Torr. Fl. U. S. 297.

Salsola Kali, var. *rosacea*. Moquin, DC. Prodr. 13^2. 188.

Salsola Tragus and *Soda*. Muhl. Cat. 28; not Linn.

2. SARCOBATUS, Nees.

Flowers monœcious or diœcious, without bracts, dimorphous. Staminate flowers in close terminal aments, without perianth, the stamens irregularly arranged around the bases of stipitate peltate scales: filaments very short: anthers fleshy. Pistillate flowers solitary, axillary; the closed perianth compressed-ovate, adherent at the contracted somewhat 2-lipped apex to the base of the stigmas, and margined laterally by a narrow erect slightly 2-lobed border, which develops into a broad membranous veined horizontal wing. Ovary thin and hyaline, nearly filled by the ovule, the slender lateral style adherent to the inner wall of the cavity and terminated by two thick exserted unequal stigmas. Seed vertical, with a transparent membranous testa: embryo green; radicle inferior. — A subspinescent rigidly branched alkaline shrub, with alternate linear fleshy leaves.

1. S. VERMICULATUS, Torrey. Erect, 3–8 feet high, leafy, smooth or at first puberulent; leaves ½–1½ inches long; male aments cylindrical, ¼–1 inch long, the scales rhomboid-ovate, acute, persistent, spirally arranged; stamens about 3 to each scale, soon deciduous; fruiting calyx coriaceous, 3 lines long, the winged margin 3–6 lines broad; pericarp distinguishable with difficulty; seed ½ line in diameter. — From the Upper Missouri and Platte to the Gila and the western border of the Great Basin. One of the more frequent of the various kinds of alkaline plants which are commonly known as "Grease-wood," and sometimes very abundant. In the immature seed the embryo may be only curved or annular.

Batis (?) *vermiculata*. Hooker, Fl. Bor.-Am. 2. 128.
Sarcobatus Maximiliani. Nees in Reise Max. v. Wied, 1. 510 and Appx. 2. 247; Bot. Zeit. 2. 547. Seubert, Bot. Zeit. 2. 753, t. 7. Lindl. in Lond. Jour. Bot. 4. 1.
Fremontia vermicularis. Torrey in Frem. Rep. 95 and 317, t. 3; (Bot. Zeit. 5. 56; Lond. Jour. Bot. 4. 481); Emory's Rep. 411. Hook. Pl. Geyer in Lond. Jour. Bot. 5. 262.
Sarcobatus vermicularis. Torrey, Emory's Rep. 149; Sitgreave's Rep. 169; Stansbury's Rep. 394; Pac. R. R. Rep. 4. 130; Bot. Wilkes's Exp. 489. Engelmann, Pl. Upp. Miss. 207. Cooper, Pac. R. R. Rep. 12. 17. Watson, King's Rep. 5. 295. Coulter, Hayden's Rep., 1872, 779. Porter, Fl. Colorado, 118.

Collectors: — James; 4 1 Fremont; 242 Geyer; Abert; Emory; Stansbury; Lyall; H. Engelmann; 23 Stretch; 185 Parry; 1844 Brewer; 3392 Bolander; 464 Torrey; 490 Vasey; 1000 Watson; Gray; 265, 266 Wolf.

3. SUÆDA, Forsk.

Flowers perfect, or rarely polygamous, minutely bracteolate. Calyx 5-parted or -cleft; the lobes fleshy, unappendaged or more or less strongly carinate or crested, or becoming somewhat winged, enclosing the fruit. Stamens 5. Styles 2, rarely 3–4, short and rather stout. Pericarp membranous, free. Seed compressed, vertical and with the radicle inferior, or horizontal; the testa smooth, black and crustaceous. — Herbs or shrubs with alternate subterete fleshy leaves, and axillary clustered or solitary flowers. (*Chenopodina*, Moq., *Schoberia*, C. A. Meyer, &c.)

* Calyx-lobes not appendaged: leaves narrow at base.

† Herbaceous annuals.

1. S. LINEARIS, Torr. MS. in herb. Smooth, nearly prostrate or ascending, rather stout, the stems 1–2 feet long, with few ascending branches; leaves subterete, ½–2 inches long, acute, the floral leaves short, ovate to lanceolate; calyx-lobes thick and strongly carinate or gibbous in fruit; stigmas 2, rarely 4; seed horizontal, ⅔ of a line broad, very obscurely reticulately marked under a lens. — Seashore lagoons, Carolina to Florida. A larger and stouter plant than *S. maritima* of Europe, the seed larger and less strongly marked. The true *maritima* is said by Hooker f. (in Fl. Arc.) to be common on the arctic coast, and to have been collected by Richardson. There are no arctic specimens in our herbariums. Moquin's species of this name is variously confused.

Chenopodium maritimum. Walter, Fl. Car. 111.
Salsola linearis. Elliott, 1. 332.
Suæda linearis. Moquin, Enum. Chenop. 130, in part.
Chenopodina linearis. Moquin, DC. Prodr. 13^2. 164, in part.
Chenopodina maritima. Chapman, 378; not L.
Collectors: — Walter; Leavenworth; Blodgett.

Var. RAMOSA. Erect and much branched, 1–2 feet high, the branches subsimple, slender, and ascending; floral leaves narrower, oblong to linear-lanceolate; seed smaller, ½ line broad. — On the seacoast from the mouth of the St. Lawrence to Southern New England and New York; Galveston (Lindheimer). Perhaps distinct, but the present material is insufficient for determination.

Salsola salsa. Michx. Flora, 1. 174. Pursh, 197. Nutt. Genera, 1. 199, in part. Bigelow, Fl. Bost. 107.
Salsola salsa, var. *Americana*. Persoon, Ench. 1. 296. Lam. Dict. 7. 288.
Chenopodium maritimum. Pursh, 198. Torrey, Fl. U. S. 296. Beck, Bot. 296. Hook. Fl. Bor.-Am. 2. 126? Hook. f., Fl. Arc. 300 and 338?

Chenopodium salsum, var. *Americanum*. Röm. & Schult. Syst. 6. 270.
Suæda linearis. Moquin, Enum. Chenop. 130, in part.
Chenopodina linearis. Moquin, DC. Prodr. 13². 164, in part.
Chenopodina maritima. Gray, Manual, 4 ed., 366. Matthew, Canad. Nat. 12. 159.
Suæda maritima. Torrey, Flora N.Y. 2. 141. Gray, Manual, 410.
Collectors: — Torrey; Lindheimer; Eaton.

2. S. DIFFUSA. Erect, 1–1½ feet high, diffusely branching with usually slender flexuous elongated branches, smooth or more or less pubescent, green or often purple; leaves subterete, ½–1 inch long, acute or acuminate, the floral ones similar but shorter, usually rather distant on the branchlets; clusters 2–4-flowered; calyx cleft to below the middle, fleshy but not carinate; seed mostly vertical, ½ line broad, perfectly smooth. — Common on the alkaline plains from Nevada and the Upper Missouri to Northern Mexico and Western Texas on the Rio Grande.

Chenopodium maritimum. Torrey, Annals N.Y. Lyc. 2. 239.
Suæda maritima. Watson in King's Rep. 5. 294.
Collectors: — James; 458 Gregg; Wright, 1848; 578 Wright, 1849, in part; 216 Palmer; 466, 66* Torrey; 996 Watson; Hayden; Gray; Wheeler.

† Perennials.

3. S. TORREYANA. Woody at base, with herbaceous leafy branches 2–3 feet high, smooth or tomentose; leaves subterete, ½–1½ inches long, mostly acute, the floral ones similar; calyx rather large, deeply cleft; seed vertical, ¾ of a line broad, rather strongly tuberculate. — In alkaline soils from the North Fork of the Platte (Fremont) to Northern Nevada, and south to Northern Mexico and Southern California. Differing from all the forms of the foreign *fruticosa* in our herbariums by its large tuberculate seeds.

Chenopodina linearis. Torrey, Stans. Rep. 394. Durand, Fl. Utah, 175.
Suæda fruticosa. Hook. & Arn. Bot. Beech. 387. Engelmann, Pl. Upp. Miss. 206.
Chenopodina Moquini. Torrey, Pac. R. R. Rep. 7. 18.
Suæda fruticosa, var. *multiflora*. Torrey, Ives's Rep. 25.
Suæda fruticosa, var. Watson, King's Rep. 5. 294.
Collectors: — Douglas; Gregg; 622 Fremont; Stansbury; 461 Torrey; 998 Watson; Cooper.

4. S. SUFFRUTESCENS. Shrubby or subshrubby, 2–3 feet high, leafy, with slender diffuse or divaricate branches, the branches more or less densely tomentose; leaves numerous and mostly small, ½ inch long or less, linear to oblong, obtuse or acute; flowers solitary or clustered; calyx small, shortly lobed; seed mostly vertical, less than ½ line broad,

very obscurely tuberculate. — From Western Texas to Southern California and Northern Mexico, in saline plains. At least in large part the *S. fruticosa*, var. *multiflora* of Torrey.

Suæda fruticosa, var. *multiflora*. Torrey, Pac. R. R. Rep. 4. 130; Bot. Mex. Bound. 184.

Collectors: — 1345 Berlandier; 578 Wright, in part; Emory.

5. S. CALIFORNICA. Stout, shrubby, 2–3 feet high, with very leafy herbaceous ascending branches, smooth or somewhat pubescent; leaves broadly linear, ½–1 inch long, acute, crowded upon the branchlets; flowers few in the axils; calyx cleft nearly to the base; seed vertical or horizontal, nearly a line broad, faintly reticulated. — Salt marshes of San Francisco Bay.

Suæda fruticosa. Moquin, DC. Prodr. 13². 156, in part. Torr. Bot. Wilkes's Exp. 439.

Collectors: — 412 Bolander; Kellogg.

* * One or more of the calyx-lobes more or less crested or transversely winged: herbaceous annuals.

6. S. DEPRESSA, Watson. Low and mostly decumbent, branching from the base, smooth, the lowest branches sometimes opposite; leaves linear, ½–1 inch long, broadest at base, the floral ones oblong- to ovate-lanceolate or ovate, acute, rather crowded upon the branchlets; calyx cleft to the middle, one or more of the acute lobes very strongly carinate or crested; seed vertical or horizontal, ½ line broad, very lightly reticulated. — From the Saskatchewan to Central Colorado and North-western Nevada.

Salsola depressa. Pursh, 197. R. & S., Syst. 6. 241. Poir. Suppl. 5. 191. Torrey, Nicollet's Rep. 159.
Salsola salsa. Nuttall, Genera, 1. 119, in part. James, Catalogue, 178.
Salsola prostrata. Torrey, Ann. N.Y. Lyc. 2. 289.
Chenopodium Americanum. Spreng. Syst. 1. 922. Dietr. Syn. 2. 994.
Chenopodium calceoliforme. Hook. Fl. Bor.-Am. 2. 126.
Schoberia Americana. C. A. Meyer in Ledeb. Fl. Alt. 1. 402.
Suæda prostrata. Moquin, Enum. Chenop. 130, in part.
Suæda calceoliformis. Moquin, l. c. 128.
Chenopodina depressa. Moquin, DC. Prodr. 13². 164. Engelm. Pl. Upp. Miss. 206. Gray, Proc. Phil. Acad., 1863, 75.
Schoberia calceoliformis. Moquin, DC. Prodr. 13². 166. Torrey, Pac. R. R. Rep. 5. 364.
Chenopodina prostrata. Bourgeau, Palliser's Rep. 260.
Suæda depressa. Watson, King's Rep. 5. 294. Porter, Hayden's Rep., 1871, 492; Fl. Col. 118.

Collectors: — James; Drummond; Nicollet; Simpson; 287 Geyer; Bourgeau; 488 Hall & Harbour, in part; 997 Watson; 486 Vasey; Allen; Lemmon; 267 Wolf.

Var. ERECTA. Erect, 1–2 feet high, the branches short and rather strict; leaves usually somewhat narrower. — From the Saskatchewan to Central Colorado and Northern Nevada; Kern County, Southern California (Blake). Dr. Torrey reports an annual species from the Lower Sacramento, California (*S. maritima*, Bot. Wilkes's Exp. 438). The specimens have not been found.

Suæda maritima. Torrey, Fremont's Rep. 95; Pac. R. R. Rep. 4. 130; and Bot. Mex. Bound. 184? Engelm. Pl. Upp. Miss. 206. Porter, Fl. Col. 118.
Chenopodina maritima. Torr. & Gray, Pac. R. R. Rep. 2. 173?
Chenopodina linearis. Torrey, Pac. R. R. Rep. 7. 18?

Collectors: — Fremont; Bourgeau; 489 Hall & Harbour; 39 Anderson; Hall, cult.; 461ª Torrey; 485 Vasey; Gray; Hayden; 341 Greene; Blake; 276 Wolf.

7. S. OCCIDENTALIS. (*Schoberia*, Watson in King's Rep. 5. 295.) Erect, slender, 8–10 inches high, smooth, with elongated flexuous spreading branches; leaves linear, ½–1 inch long, acute, narrow at base, the floral leaves somewhat widest; flowers few in the axils; calyx cleft nearly to the middle, with obtuse lobes, at length surrounded by a transverse irregularly lobed veinless wing, a line broad; seed horizontal, ½ line broad, obscurely reticulated. — Ruby Valley, Nevada; collected only by Watson (999). Closely resembling the last, but differing in habit and in the more decidedly winged fruit.

4. APHANISMA, Nutt.

Flowers perfect. Calyx 3-cleft, adnate at base to the ovary, not becoming thickened or appendaged. Stamen 1. Ovary ovate: style short, persistent, with 2–3 very short stigmas. Pericarp rather thick and indurated, somewhat angular, surrounded at base by the dry calyx. Seed lenticular, with a very thin crustaceous testa. — A smooth herbaceous annual, with alternate sessile entire leaves and minute axillary sessile mostly solitary flowers.

1. A. BLITOIDES, Nutt. (Moquin in DC. Prodr. 13^2. 54.) Slender, 1–1½ feet high, rooting at base, branched; leaves thin, ovate, cordate-ovate or ovate-oblong, ½–1 inch long, acute; fruit ⅓–½ line broad; seed punctulate-rugose, shining. — Collected only by Nuttall at San Diego, California.

5. TELOXYS, Moquin.

Flowers perfect or sometimes pistillate. Calyx 5- (rarely 4-) parted, the lobes more or less prominently carinate and subcrested. Stamen 1

(5, *Moquin*) or wanting. Ovary ovate: styles 2, free or united at base. Fruit partially covered by the loosely appressed calyx; pericarp membranous. Seed lenticular, with a crustaceous testa. — Herbaceous annuals, erect and diffuse; the minute solitary flowers very shortly pedicelled, axillary and terminal upon the repeatedly dichotomous nearly naked branches; terminal flowers abortive and deciduous, leaving the ultimate branchlets spinulose: leaves thin, alternate.

1. T. ARISTATA, Moquin. Glabrous, 6 inches high; leaves entire, linear to linear-lanceolate, 1–3 inches long; flowers enlarged in fruit, the loose calyx becoming ½ line long, with obtuse lobes, scarcely carinate, not crested; fruit dark brown, the seed acutely margined. — Northern Asia and reported from Alaska. The plant on which the species was originally founded was doubtfully and probably erroneously ascribed to Virginia.

Chenopodium Virginicum. Linn. Spec. 1. 222.
Chenopodium aristatum and var. *Virginicum*. Linn. Spec., 2 ed., 321. Gmelin, Fl. Sib. 3. 83, t. 15.
Teloxys aristata. Moquin, Ann. Sci. Nat. 2. 1. 289, t. 10; Enum. Chenop. 17; DC. Prodr. 13^2. 59. Fenzl in Ledeb. Fl. Ross. 3. 693. Rothrock, Fl. Alaska, 455. Torrey, Pac. R. R. Rep. 4. 129.

2. T. CORNUTA, Torrey. Slender, ½–1½ feet high, glabrous or somewhat glandular-puberulent, the calyx resinous-dotted; leaves lanceolate, repand-dentate with 2–3 distant lobes on each side, 1–2 inches long, attenuate to a slender petiole; flowers very small, mostly perfect; calyx-lobes acute, carinate with a short thick crest, more appressed; fruit light brown, depressed-globose; seed obtusely margined. — From Colorado to New Mexico, Western Arizona and Northern Mexico.*

Teloxys cornuta. Torr. Pac. R. R. Rep. 4. 129; Bot. Mex. Bound. 182. Porter, Hayden's Report, 1870, 480; Fl. Colorado, 116.
Collectors: — No. 1785 Wright; 390 Gregg; Woodhouse; 2 Palmer; Greene.

6. CYCLOLOMA, Moquin.

Flowers perfect or sometimes pistillate. Calyx urceolate, 5-cleft, the concave acute lobes carinate, becoming closely appressed and developing a broad transverse membranous wing. Stamens 5. Ovary

* A third species was collected by Mandon (No. 1026) in the Andes of Bolivia, and may be named T. MANDONI. It is stout, 1–2 feet high, glandular-puberulent throughout; leaves rather thick, oblong-lanceolate, 2 inches long, sinuately pinnatifid; calyx-lobes strongly carinate, slightly crested, obtuse, appressed; fruit dark brown; seed obtusely margined.

depressed: styles 3 or 2. Pericarp membranous, pubescent. Seed lenticular. — An erect herbaceous annual, with alternate thin leaves, and very small solitary axillary flowers in open panicles.

1. C. PLATYPHYLLUM, Moquin. Diffuse, 6–15 inches high, more or less arachnoid-pubescent, becoming glabrous; leaves lanceolate, 1–2 inches long, acute, attenuate to a slender petiole, coarsely sinuate-toothed; calyx cleft to the middle, becoming with the irregularly lobed and toothed wing 2 lines broad, wholly covering the utricle; ovary very pubescent; fruit a line broad. — From Missouri to the Upper Platte and southward to Arkansas and New Mexico. Whole plant light green or often deep purple. First collected by Michaux and introduced by him into the gardens of Europe in 1796 or soon after, where it was cultivated under many different names.

Salsola atriplicifolia. Spreng. Nacht. h. Hall. 1. 35 (1801). Lam. Dict. 7. 297.
Kochia atriplicifolia. Roth, Neue Beyträge, 1. 177.
Salsola radiata. Desf. Ann. Mus. 2. 28, t. 34 (1803); Ann. of Bot. 2. 337. Spreng. Syst. 1. 923. Dietrich, Syn. 2. 996.
Salsola platyphylla. Michaux, Flora, 1. 174 (1803). Willd. Enum. 293. Persoon, Ench. 1. 297.
Kochia dentata. Willd. Hort. Berol., t. 28 (1806). Pursh, 206. Torrey, Ann. N.Y. Lyc. 2. 239; Nicollet's Rep. 158. Nuttall, Fl. Ark. 165.
Salsola latifolia. Lam. Dict. 7. 298.
Chenopodium radiatum. Schrad. Neues Journ., 1809, 85, t. 3. Persoon, Ench. 1. 297.
Salsola Atriplicis. Schult. Obs. Bot. 52.
Amoreuxia platyphylla. Moquin, Soc. Hist. Monsp., 1826.
Cyclolepis platyphylla. Moquin, Ann. Sci. Nat. 2. 1. 203.
Cycloloma platyphyllum. Moquin, Enum. Chenop. 18; DC. Prodr. 13². 60. Torrey, Fremont's Rep. 95; Sitgreave's Rep. 169; Pac. R. R. Rep. 4. 129. Engelm. Pl. Upp. Miss. 206. Gray, Am. Jour. Sci. 2. 34. 258. Porter, Hayden's Rep., 1870, 480; Fl. Col. 116.
Amorea platyphylla. Delile, Cat. h. Monsp., 1844.

Collectors: — James; Nuttall; Fremont; 1736 Wright; G. Engelmann; Bigelow; H. Engelmann; 274 Palmer; Patterson; Vasey.

7. KOCHIA, Roth.

Flowers perfect or pistillate, bractless, solitary or few in the axils of the leafy stems. Calyx herbaceous, subglobose, 5-cleft, persistent over the fruit and usually with a more or less complete transverse lobed wing. Stamens 5. Ovary depressed: styles 2, filiform. Pericarp membranous. Seed compressed, with a membranous testa: embryo green,

cotyledons thick: albumen scanty or none. — Perennials, woody at base, with scattered linear terete leaves.

1. K. Americana. Stems erect and virgate, mostly simple, 6–18 inches high, tomentose and somewhat villous or nearly glabrous; leaves 3–12 lines long, cuspidate or acutish, ascending; flowers mostly with rudimentary stamens, 1–3 in each axil, densely white-tomentose, nearly a line broad in fruit and the membranous wing often as broad or broader, the cuneate-rounded segments nerved and subcrenulate; ovary ovate, densely tomentose at the apex, much shorter than the calyx and the elongated exserted styles; fruit nearly smooth, scarcely apiculate; seed ⅔ of a line broad, without albumen, the acuminate radicle-sheath partially including the cotyledons. — Foothills and valleys from Northern Nevada to Southern Wyoming and southward to Arizona and Southern Colorado. It much resembles *K. prostrata* of the Old World, to which it has hitherto been referred, but which differs especially in its glabrous utricle being prominently beaked below the style, in its larger seed with a scanty albumen, and in the radicle-sheath less prolonged. The genus shows an approach to *Suæda* and the *Spirolobeæ* in the want of albumen and the somewhat more than annular embryo. The *Kochia dioica* of Nuttall proves to be *Chenopodium Endolepis*, the *Endolepis Suckleyana* of Torrey.

Kochia prostrata. Hook. Pl. Geyer in Lond. Jour. Bot. 5. 262; not Schrad. Watson, King's Rep. 5. 298, in part. Coulter, Hayden's Rep., 1872, 779.

Collectors: — 465 Torrey; 992 Watson; Greene; Wheeler.

Var. vestita. Densely villous throughout and subtomentose; ovary oblong, nearly equalling the calyx, very pubescent. — Shores of Great Salt Lake (991 Watson), and on the line of the Pacific Railroad in Nevada or Utah (Burgess).

8. CHENOPODIUM, Linn.

Flowers perfect, or sometimes pistillate, bractless. Calyx 5- (rarely 3–4-) parted, the lobes usually somewhat carinate or crested. Stamens 5. Ovary depressed: styles 2, rarely 3 or 4, slender. Pericarp membranous, closely investing the seed and more or less completely enveloped by the dry calyx. Seed lenticular, with crustaceous testa, sometimes vertical in § *Botryois*. — Herbaceous and mostly annual, usually white-mealy or glandular, with alternate petioled leaves and sessile clustered flowers in axillary and terminal or panicled spikes.

§ 1. Annuals, usually more or less farinose, not pubescent nor glandular, nor sweet-scented. Embryo completely surrounding the albumen. — *Chenopodiastrum*, Moquin.

* Pericarp very easily separated from the seed. Leaves entire or rarely sinuate-dentate, often hastate-lobed. Native species.

1. C. Boscianum, Moq. Erect, slender, 2 feet high, loosely branched, nearly glabrous; leaves thin, oblong- to linear-lanceolate, 1–2 inches long, acute, attenuate into a long slender petiole, the lower sinuate-dentate or often all entire; flowers very small, solitary or in small clusters upon the slender branchlets; calyx green, not strongly carinate, partially covering the at length naked seed, which is half a line broad. — Pennsylvania and Kentucky to "Carolina" (Chapman) and Texas.

Chenopodium Boscianum. Moquin, Enum. Chenop. 21; DC. Prodr. 13^2. 61. Chapman, 376.
Chenopodium polyspermum, var. *spicatum.* Gray, Manual, 2 ed., 368.
Chenopodium album, var. *Boscianum.* Gray, Manual, 407, excl. syn. *C. Berlandieri.*

Collectors: — 246 Drummond; 2398 Berlandier; Short; Porter; Green.

2. C. Fremontii, Watson. Erect, slender, 1–2 feet high, branching, somewhat mealy; leaves broadly triangular-hastate, ½–1 inch long, with obtuse or abruptly acute lobes, truncate or cuneate at base, the upper sometimes becoming oblong to linear-lanceolate, entire, with long petioles; flowers small, mealy, scattered in few-flowered clusters upon the slender open panicled branchlets, the sepals strongly carinate, nearly covering the mature fruit; seed half a line broad. — From Colorado to the Sierra Nevada and southward to New Mexico.

Chenopodium Fremontii. Watson, King's Rep. 5. 287. Porter, Fl. Col. 117.

Collectors: — Fremont; 570, 1734 Wright; 978 Watson; 484 Vasey; Cooper; 387 Greene.

Var. incanum. Densely farinose, low and rather stout, 3–6 inches high, diffusely branched; flowers crowded in close contracted panicles; leaves thick, ½ inch long or less, hastately lobed. — Colorado and New Mexico.

Collectors: — Marcy; 722 Fendler; 389 Greene.

3. C. leptophyllum, Nutt. Densely mealy or rarely nearly glabrous, ½–1½ feet high, simple or branched, often strict; leaves linear, ½–1 inch long, entire, acute and usually mucronate, rather

shortly petioled; flowers small, closely clustered, in dense or interrupted spikelets; calyx-lobes strongly carinate, scarcely covering the fruit; seed ½ line broad. — From Colorado to Nevada and southward to New Mexico; also collected by Professor D. C. Eaton at Absecom in New Jersey.

Kochia dioica. James, Catalogue, 178; not Nuttall. Torrey, Ann. N.Y. Lyc. 2. 289.
Chenopodium, n. sp. Torrey, Nicollet's Rep. 159.
Chenopodium zosterifolium. Torrey, Fremont's Rep. 95; not Hooker.
Chenopodium leptophyllum. Nutt. MS. in herb.
Chenopodium album, var. *leptophyllum.* Moquin, DC. Prodr. 13^2. 71. Watson, King's Rep. 5. 287. Coulter, Hayden's Rep., 1872, 779.

Collectors: — James; 283 Nicollet; Fremont; 1731 Wright; Eaton; 971, 972 Watson; 338 Greene; 264 Wolf.

Var. SUBGLABRUM. Nearly glabrous, loosely branched and panicled, the clusters few-flowered and scattered on the branchlets. — Sandhills of the Platte (Hayden).

Var. OBLONGIFOLIUM. Rather stout, 6–10 inches high, branched, densely mealy; leaves oblong, often slightly hastate, ½–¾ inch long, obtuse or acutish; flowers in dense clusters in short close spikes. — From Colorado to New Mexico; 717 Fendler; 1732, 1733 Wright.

** Pericarp persistent upon the smooth seed. Leaves more or less sinuate-dentate except in *C. olidum* and *polyspermum*. Most of the species introduced.

4. C. BERLANDIERI, Moq. Somewhat mealy or nearly smooth, 2–3 feet high, the branches slender and loosely spreading; leaves rhombic-oblong or oblong-lanceolate, an inch long or less, often subhastate and usually sinuate-dentate and very acutely or setaceously acuminate, the lobes or teeth acute; flowers mostly in slender loose interrupted spikes, nearly as large as in *C. album*, but the seed smaller (½ line wide). — Texas; Western Florida.

Chenopodium Berlandieri. Moquin, Enum. Chenop. 23; DC. Prodr. 13^2. 68.
Chenopodium album, var. *Boscianum.* Gray, Manual, 407, in part.

Collectors: — 526, 968, 1906 Berlandier; 281 Lindheimer; Chapman.

5. C. OLIDUM. Rather stout, farinose, heavy scented, 3–18 inches high, branching; leaves rather thick, oblong to broadly ovate, 6–9 lines long, often slightly hastate, entire, obtuse or acute, apiculate, on slender petioles; flowers usually large, nearly a line in diameter in fruit, in close clusters rather loosely panicled; pericarp mealy, very closely adherent to the large seed. — Colorado to Salt Lake Valley

and southward to New Mexico and Arizona. Seeds gathered by the Indians of Arizona for food.

Chenopodium album. Watson, King's Rep. 5. 287, in part.

Collectors:—882 Fremont; 718, 721, 725[b] Fendler; Hall & Harbour; 970 Watson; Hall, cult. from Powell's seeds; 258 Wolf.

6. C. ALBUM, Linn. Usually 2–4 feet high, erect, simple or branched, more or less mealy; leaves subrhombic-ovate, 1–3 inches long, obtuse or acute, cuneate at base, at least the lower ones sinuate-dentate, the upper usually entire and lanceolate to linear, or all narrowly lanceolate to linear; flowers rather large, densely clustered in usually close spikes, the panicle strict and close or somewhat spreading; calyx about $\frac{3}{4}$ of a line wide in fruit, the lobes strongly carinate, nearly or quite covering the seed.—Everywhere introduced. Western specimens are mostly near the typical form, quite mealy, nearly simple, and with close contracted panicles. The var. VIRIDE, which is the more common eastward, is less mealy and with a less dense inflorescence.

Chenopodium lanceolatum. Muhl. in Willd. Enum. 1. 291.

Chenopodium subspicatum. Torrey, Ann. N.Y. Lyc. 2. 289, not of Nuttall; Marcy's Rep. 296.

Chenopodium ficifolium? Hook. & Arn. Bot. Beech. 157?

Chenopodium album, var. *concatenatum.* Moquin, Enum. Chenop. 30.

Chenopodium album, Linn. Hook. Fl. Bor.-Am. 2. 127; Comp. Bot. Mag. 2. 61; Pl. Geyer in Lond. Jour. Bot. 5. 261. Benth. Pl. Hartw. 332. Torrey, Nicollet's Rep. 159; Fremont's Rep. 95; Emory's Rep. 411; Pac. R. R. Rep. 4. 129; Bot. Mex. Bound. 182. Scheele, Linnæa, 22. 151. Engelm. Pl. Upp. Miss. 617. Seemann, Bot. Herald, 58. Parry, Pl. Minnesota, 617. Cooper, Pac. R. R. Rep. 12. 68. Gray, Proc. Amer. Acad. 5. 167; Manual, 407. Chapman, 376. Hook. f., Fl. Arct. 300. Bourgeau, Palliser's Rep. 260. Watson, King's Rep. 5. 287. Bolander, Catalogue, 25. Porter, Hayden's Rep., 1871, 492; Fl. Col. 116. Coulter, Hayden's Rep., 1872, 779. Torr. Bot. Wilkes's Exp. 436.

Collectors:—Richardson; Fremont; 1938 Hartweg; 725 Fendler; Lyall; Gray; Horn; 787 Brewer; Peckham; 725[a] Palmer; 245 Anderson; 969 Watson.

7. C. POLYSPERMUM, Linn. Not mealy, erect, $\frac{1}{2}$–2 feet high, simple or branched; leaves thin, ovate-oblong, 1–2 inches long, entire, obtuse or acute, cuneate at base; flowers small, in few-flowered clusters usually scattered in short very slender axillary spikes or panicles; calyx smooth, scarcely carinate, not covering the fruit; seed less than half a line broad. — Introduced into the Eastern states; rare.

Chenopodium polyspermum. Gray, Manual, 406.

8. C. HYBRIDUM, Linn. Not mealy, rather stout, erect, 2–4 feet high, simple or sparingly branched above; leaves usually large, 2–6

inches long, broadly ovate, acuminate, subcordate at base, sinuate-dentate with 2–3 distant teeth on each side; flowers in small clusters in slender terminal and axillary panicles; seed ⅔ of a line broad, the margin acutish. — Introduced eastward, but indigenous from Kentucky, Texas, and New Mexico to Oregon.

Chenopodium urbicum? Hooker, Fl. Bor.-Am. 2. 127.
Chenopodium hybridum, var. *simplex*. Torrey, Ann. N.Y. Lyc. 2. 289.
Chenopodium hybridum, Linn. Torrey, Nicollet's Rep. 159; Pac. R. R. Rep. 4. 129. Nuttall, Fl. Ark. 165. Scheele, Roemer's Texas, 445. Carey, Am. Jour. Sci. 2. 7. 170. Gray, Proc. Acad. Phil., 1863, 75; Manual, 407. Bourgeau, Palliser's Rep. 260. Watson, King's Rep. 5. 287. Porter, Hayden's Rep., 1871, 492; Fl. Col. 117. Coulter, Hayden's Rep., 1872, 779.

Collectors: — James; Richardson; 284 Nicollet; 142, 189 Fremont; 715 Fendler; 280 Lindheimer; Wright; Lyall; Parry; 485 Hall & Harbour; 974 Watson; Vasey; 257 Wolf.

9. C. MURALE, Linn. Slightly mealy, stout, ascending or decumbent, 1–2 feet high; leaves mostly large, broadly triangular to lanceolate, 1–3 inches long, acute, truncate or cuneate at base, coarsely sinuate-dentate; flowers in small clusters in axillary usually rather dense spicate panicles, mostly shorter than the leaves; seed acutely margined. — Introduced eastward, and found on the western coast from San Francisco to Southern California.

Chenopodium urbicum. Bolander, Catalogue, 25.
Chenopodium murale, Linn. Hook. & Arn. Bot. Beechey, 157. Carey, Am. Jour. Sci. 2. 7. 170. Bromfield, Hook. Lond. Jour. Bot., 1848, 211. Chapman, 376. Gray, Manual, 407.

Collectors: — 96, 2387 Brewer; Horn; Gregg; Greene.

Var. FARINOSUM. Leaves glaucous-mealy beneath; flowers densely clustered in short axillary spikes; pericarp membranous and not closely adherent. — A remarkable and probably distinct form, reported as common in moist places near San Francisco (2489 Brewer).

10. C. URBICUM, Linn. Erect, 1–3 feet high; flowers in slender spicate panicles, at least the upper ones exceeding the leaves; margin of the seed obtuse or acutish; otherwise like *C. murale*. — Introduced, in the Eastern states.

Chenopodium rhombifolium. Muhl. in Willd. Enum. 1. 288. R. & S., Syst. 6. 256. Bromfield, Hook. Jour. Bot., 1848, 211. Carey, Am. Jour. Sci. 2. 7. 169.
Chenopodium urbicum, var. *rhombifolium*. Moquin, Enum. Chenop. 32; DC. Prodr. 13^2. 70. Gray, Manual, 407.
Chenopodium urbicum, Linn. Engelm. Pl. Upp. Miss. 206. Gray, Manual, 407.

§ 2. Not mealy, but more or less glandular-pubescent, aromatic. Seed obtusely margined, scarcely a third of a line broad, often vertical in a 2–3-sepaled calyx. Embryo imperfectly annular. — § BOTRYOIS, Moquin. Introduced from Tropical America.

11. C. BOTRYS, Linn. Viscid throughout, erect, 1–2 feet high, branched; leaves ovate to oblong, 1–2 inches long, obtuse, truncate or cuneate at base, sinuately pinnatifid and the lobes usually toothed; flowers subsolitary in naked slender diffuse axillary panicles; calyx-lobes acute, loosely enclosing the fruit; pericarp persistent. — Collected in Oregon and Utah, and common eastward.

Chenopodium Botrys, Linn. Pursh, 198. Nuttall, Genera, 1. 199. Elliott, 1. 180. Hooker, Comp. Bot. Mag. 2. 61. Chapman, 376. Gray, Man. 407. Watson, King's Rep. 5. 288.
Ambrina Botrys, Moquin. Torrey, Flora N.Y. 2. 184.

Collectors: — 854 Kell. & Harford; 975 Watson.

12. C. AMBROSIOIDES, Linn. Smoothish, scarcely glandular, erect or ascending, 2–3 feet high, usually stout and branched; leaves lanceolate, 2–5 inches long, sinuate-dentate, or the upper linear-lanceolate and entire, acute, attenuate to a short petiole; flowers in dense axillary clusters or short simple dense axillary spikes upon the leafy branches; calyx-lobes obtuse, appressed; styles 3, sometimes 4; pericarp deciduous. — Eastward, and in California from San Francisco to San Diego.

Chenopodium ambrosioides, Linn. Hooker, Comp. Bot. Mag. 2. 61. Hook. & Arn. Bot. Beech. 157. Nuttall, Fl. Ark. 165. Engelm. Pl. Upp. Miss. 206. Torrey, Pac. R. R. Rep. 7. 18. Gray, Manual, 408.
Ambrina ambrosioides, Spach. Torrey, Flora N.Y. 2. 185.
Roubieva ambrosioides. Carey, Am. Jour. Sci. 2. 7. 169.
Chenopodium anthelminticum. Bolander, Catalogue, 25; not Linn.

Collectors: — 6461 Bolander; 82, 2402 Brewer; 426 Cooper; 3202 Berlandier; Lindheimer; Parry.

Var. ANTHELMINTICUM, Gray. Spikes more elongated, often compound and bractless; leaves usually more deeply toothed; said to be perennial. — From the Mississippi and Texas eastward.

Chenopodium anthelminticum, Linn. Michaux, Flora, 1. 178. Raf. Med. Flora, 1. 103, fig. 21. Hooker, Comp. Bot. Mag. 2. 61. Moquin, DC. Prodr. 13^2. 73. Torrey, Bot. Mex. Bound. 182. Chapman, 377.
Ambrina anthelmintica, Spach. Torrey, Flora N.Y. 2. 185.
Roubieva anthelmintica. Carey, Am. Jour. Sci. 2. 7. 169.
Chenopodium ambrosioides, var. *anthelminticum*. Gray, Manual, 408.

Doubtful Species.

13. C. CARNOSULUM, Moquin, DC. Prodr. 13^2. 64. Described from a specimen in herb. Hooker, said to be from California, but collector unknown. The only certain locality is Port Gregory in extreme Southern America, where it was collected by R. O. Cunningham. It resembles reduced small-leaved forms of *C. Fremontii*, but has the leaves more shortly petioled and the flowers more crowded and axillary.

9. ROUBIEVA, Moquin.

Flowers perfect or pistillate, solitary or mostly 2–3 together in the axils. Calyx deeply urceolate, 3–5-toothed, in the pistillate flowers much smaller, becoming contracted at the apex and saccate, 3–5-nerved and reticulately veined. Stamens 5, included. Ovary glandular at the top: styles 3, exserted in the pistillate flowers. Achenium membranous, glandular-dotted, the styles somewhat lateral. Seed vertical.—A perennial heavy-scented South American herb, with alternate pinnatifid leaves.

1. R. MULTIFIDA, Moquin. Prostrate or ascending, diffuse, glandular-puberulent, leafy; leaves lanceolate, ½–1½ inches long; perfect and pistillate flowers intermingled; fruiting calyx nearly a line long, obovate; pericarp membranous, persistent.—Rarely occurring in some of the Atlantic states.

Chenopodium multifidum, Linn. Gray, Manual, 408.

Roubieva multifida. Moquin, Ann. Sci. Nat. 2. 1. 292, t. 10; DC. Prodr. 13^2. 80. Carey, Am. Jour. Sci. 2. 7. 167; Bot. Zeit. 8. 528. Gray, Manual, 2 ed., 364. Smith, Proc. Acad. Phil., 1867, 22.

10. BLITUM, Tourn.

Flowers perfect or pistillate, bractless. Calyx 2–5-parted or -cleft, unchanged in fruit or fleshy and juicy, not appendaged. Stamens 1–5. Styles 2. Fruit compressed, vertical, partially enclosed in the appressed calyx. Pericarp usually not adherent to the compressed-globose or lenticular seed. Embryo surrounding the albumen.—Herbs, mostly annual, with alternate petioled leaves and densely clustered flowers.

§ 1. Annual or biennial, glabrous. Flowers in axillary heads or the uppermost interruptedly spicate. Calyx becoming more or less fleshy.

1. B. RUBRUM, Reich. Stout, erect, 1–3 feet high, branched and leafy; leaves triangular-hastate to lanceolate, 2–3 inches long, acute, cuneate

at base, sparingly sinuate-dentate, the upper narrowly lanceolate and entire; flower-clusters densely spicate upon the branchlets; calyx-lobes 2–4, obtuse, rather fleshy; stamens 1–2; margin of the seed obtuse or acutish. — Seacoast of the Northern states and in saline places inland to the Saskatchewan. Not separable from the European form.

Chenopodium rubrum. Linn.
Blitum maritimum. Nuttall, Genera, 2. Addenda. Moquin, Enum. Chenop. 44; DC. Prodr. 18^2. 82. Torrey, Fl. U. S. 5; Fl. N.Y. 2. 136. Bourgeau, Palliser's Rep. 260. Porter, Hayden's Rep., 1870, 481.
Blitum polymorphum. C. A. Meyer, Ledeb. Fl. Alt. 1. 13. Watson, King's Rep. 5. 288.
Blitum rubrum. Reich. Fl. Germ. Exc. 582; Moquin, DC. Prodr. 18^2. 83. Hook. Fl. Bor.-Am. 2. 127.

Collectors: — Bourgeau; Torrey; Clinton; Oakes.

Var. HUMILE, Moquin. Stems 3–6 inches long, prostrate or ascending; leaves an inch long or less, ovate to lanceolate, often hastate, rarely toothed; flowers in solitary or subspicate clusters. — From the Saskatchewan to Central Colorado, Northern Nevada and North-eastern California.

Chenopodium humile. Hook. Fl. Bor.-Am. 2. 127.
Blitum polymorphum, var. *humile.* Moquin, Enum. Chenop. 46. Watson, King's Rep. 5. 288. Coulter, Hayden's Rep., 1872, 779.
Blitum rubrum. Newberry, Pac. R. R. Rep. 6. 87.
Blitum rubrum, var. *humile.* Moquin, DC. Prodr. 18^2. 84. Cooper, Pac. R. R. Rep. 12. 68. Bourgeau, Palliser's Rep. 260. Porter, Hayden's Rep., 1871, 492.

Collectors: — Drummond; Bourgeau; Newberry; 462 Torrey; 978 Watson; 272 Wolf.

2. B. CAPITATUM, Linn. Erect, simple or sparingly branched, 1–2 feet high; leaves broadly triangular to lanceolate, 1–3 inches long, often somewhat halbert-shaped or hastate, cuneate or hollowed at base, sharply sinuate-toothed or entire; flower-clusters usually large, in interrupted terminal simple naked spikes and solitary in the axils of the upper leaves; stamens 1–5; calyx becoming fleshy and the clusters red and berry-like; seed small and somewhat acutely margined, the pericarp adherent. — From the Northern border states to Hudson Bay, Great Bear Lake and Oregon, and southward in the mountains to New Mexico and Utah.

Blitum capitatum, Linn. Michaux, Flora, 1. 2. Pursh, 4. Richardson, Appx. to Frankl. Journ. 27. Hook. Fl. Bor.-Am. 2. 126. Seemann, Bot. Herald, 53. Torrey, Flora N.Y. 2. 136; Pac. R. R. Rep. 4. 129. Bourgeau, Palliser's Rep. 260. Rothrock, Fl. Alaska, 455. Matthew, Canad. Nat. 12. 158. Gray, Manual, 408. Watson, King's Rep. 5. 288. Porter,

Hayden's Rep., 1870, 481; 1871, 492; Fl. Col. 117. Coulter, Hayden's Rep., 1872, 779.

Collectors: — Richardson; 720 Fendler; Bourgeau; Lyall; Hall & Harbour; 976, 977 Watson; 481 Vasey.

§ 2. Herbaceous, mostly perennial, somewhat mealy. Calyx not becoming fleshy. Flowers in dense terminal spikes (or axillary in *B. glaucum*). — § AGATHOPHYTON, Moquin.

3. B. GLAUCUM, Koch. Annual, low, ½–1 foot high, usually decumbent, branching, glaucous-mealy, the upper surface of the leaves smooth; leaves ovate to oblong-lanceolate, ½–1 inch long, obtuse, attenuate to a slender petiole, sinuate-dentate; flowers clustered in axillary spikes shorter than the leaves; calyx small, not covering the fruit. — Introduced in the Eastern states from Europe, but apparently indigenous on the Saskatchewan and in Colorado in saline localities.

Chenopodium glaucum, Linn. Hook. Fl. Bor.-Am. 2. 127. Bromfield in Hook. Journ. Bot., 1848, 211. Carey, Am. Jour. Sci. 2. 7. 169. Moquin, DC. Prodr. 13^2. 72. Engelm. Pl. Upp. Miss. 206. Bourgeau, Palliser's Rep. 260. Gray, Manual, 407. Porter, Fl. Col. 117.

Blitum glaucum. Koch, Syn. Fl. Germ. 608.

Collectors: — Drummond; Bourgeau; 482 Vasey; Greene; 254 Wolf.

4. B. BONUS-HENRICUS, C. A. Meyer. Stout, erect, 1–2 feet high, mostly simple; leaves broadly triangular-hastate, 2–3 inches long, obtuse or acute, hollowed at base, subsinuate or entire; flowers somewhat densely paniculately spiked; calyx deeply parted, nearly equalling the fruit; stamens 5; styles 2–5; pericarp adherent; seed obtusely margined. — European; scarcely introduced.

Chenopodium Bonus-Henricus, Linn. Pursh, 197. Torrey, Fl. U. S. 294.

Blitum Bonus-Henricus. C. A. Meyer, Ledeb. Fl. Alt. 1. 11. Moquin, DC. Prodr. 13^2. 84. Gray, Manual, 408.

5. B. CALIFORNICUM. Resembling the last, but the leaves acuminate, sharply and unequally sinuate-dentate; calyx more or less deeply 5-cleft, nearly enveloping the fruit; seed less compressed, nearly globose, ¾–1 line broad; flowers often pedicelled, loosely clustered. — California, from the Sacramento to Fort Tejon and San Diego. Known in the southern part of the state as "Soap-plant."

Roubieva anthelmintica. Hook. & Arn. Bot. Beech. 387.

Chenopodium anthelminticum, var. (?) *hastatum*. Moquin, DC. Prodr. 13^2. 74.

Blitum Bonus-Henricus, var. *erosum*. Moquin, DC. Prodr. 13^2. 85.

Blitum Bonus-Henricus. Torrey, Pac. R. R. Rep. 4. 129; same, 7. 18; Bot. Mex. Bound. 182.

Blitum rubrum? Torr. Bot. Wilkes's Exp. 437.

Collectors: — Coulter; Fremont; Bigelow; Parry; Torrey; 104 Xantus; 244, 1065 Brewer; 448 Cooper; 855 Kellogg & Harford.

11. MONOLEPIS, Schrad.

Flowers polygamous, bractless, the calyx of a single persistent scalelike or foliaceous sepal, not appendaged. Stamen 1, with didymous anther-cells. Styles 2, filiform. Utricle compressed, persistent upon the vertical flattened seed. Embryo surrounding the albumen; radicle inferior. — Low annual herbs, with petioled leaves, and flowers in axillary clusters.

1. M. CHENOPODIOIDES, Moquin. Glabrous or somewhat mealy; stems ascending, much branched from the base, 3–12 inches high; leaves lanceolate-hastate, 1–3 inches long, acute or acuminate, attenuate at base and the lateral lobes acute, sparingly sinuate-dentate or entire, the upper leaves much smaller, ½ inch long or less; flower-clusters dense, often reddish; sepal fleshy and foliaceous, oblanceolate or spatulate, acute; pericarp adherent, minutely subreticulately pitted; seed ½ line broad, the margin acutish. — From the Saskatchewan to New Mexico, Arizona, and Northeastern California.

Blitum chenopodioides. Nuttall, Genera, 1. 4. James, Catalogue, 172. Torrey, Ann. N.Y. Lyc. 2. 240. Hook. Fl. Bor.-Am. 2. 126.
Blitum Nuttallianum. Roem. & Schult. Mant. 1. 65. Moquin, Enum. Chenop. 45.
Monolepis Nuttalliana. Engelm. Pl. Upp. Miss. 206. Bourgeau, Palliser's Rep. 260. Gray, Proc. Phil. Acad., 1863, 75.
Monolepis chenopodioides. Moquin, DC. Prodr. 13^2. 85. Engelm. Pl. Upp. Miss. 206. Watson, King's Rep. 5. 288. Porter, Hayden's Rep., 1871, 492; Fl. Col. 117. Coulter, Hayden's Rep., 1872, 779.
M. chenopodioides, var. *trifida.* Torrey, Ives's Rep. 25; not Moq.

Collectors: — Richardson; Nicollet; 477 Fremont; Newberry; Bourgeau; 54 Palmer; Torrey; 486 Hall & Harbour; 491 Vasey; 979 Watson; Hayden; 340 Greene; Bolander & Kellogg.

2. M. SPATHULATA, Gray. Decumbent or ascending, 3–6 inches high, with elongated leafy branches, subpuberulent or glabrous; leaves narrowly spatulate, ½ inch long or less, acute, entire; clusters dense, 10–20 flowered; sepal spatulate, obtuse; pericarp separating from the seed, minutely papillose; seed less than ¼ line broad. — Mono Pass, California (6373 Bolander), and by Kellogg, but locality not given.

Monolepis spathulata. Gray, Proc. Am. Acad. 8. 389. Watson, King's Rep. 5. 289.

3. M. PUSILLA, Torrey. Erect, dichotomously much branched from the base, 2–6 inches high, slender, somewhat mealy becoming glabrous, often reddish; leaves oblong, 3–6 lines long, obtuse, entire, shortly

petioled; clusters 1–5-flowered; sepal obtuse; pericarp adherent, minutely tuberculate; seed less than $\frac{1}{2}$ line broad, acutish on the margin. — Alkaline valleys of Northwestern Nevada.

Monolepis pusilla. Torrey; Watson, in King's Rep. 5. 289.

Collectors: — Stretch; 228 Anderson; 980 Watson; Gray.

12. ATRIPLEX, Tourn.

Monœcious or diœcious. Staminate flowers bractless, the campanulate calyx 3–5-cleft or -parted, with as many stamens. Pistillate flowers 2-bracted, without calyx* or rarely with 2–4 free hyaline sepals: bracts erect, free or more or less united, becoming enlarged and enclosing the fruit; the margins usually somewhat dilated, toothed or entire, and the sides often thickened and muricate. Styles 2, filiform, free or united at base. Fruit compressed, sessile or stipitate; the pericarp thin and membranous. Seed vertical, with a thin crustaceous or coriaceous testa: radicle inferior, ascending, or superior. — Herbs or shrubs, mealy or scurfy-tomentose. Leaves flat, alternate or opposite, often hastate or sinuate-dentate. Flowers usually clustered, axillary, or in simple or panicled spikes, the male and female distinct upon the same or separate plants or mingled in the clusters.

SECT. I. Annuals: radicle inferior or subascending: bracts free or nearly so.

§ 1. Bracts ovate-rhombic to triangular or hastate, often appendaged, the margin foliaceous, entire or toothed; leaves subhastate.

Spikes naked; leaves petioled, green . . . . . . 1. *A. patula.*
Spikes mostly leafy; leaves nearly sessile, gray scurfy. Introduced, rare . . . . 2. *A. rosea.*

§ 2. Bracts ovate to linear, mostly 4–6 lines long, entire and not margined nor appendaged (except in No. 3), only the apex foliaceous.

* Leaves alternate.

Subdiœcious; leaves hastate, subentire; bracts linear-lanceolate, often toothed at base, 3-nerved, styles included; calyx 5-cleft. Western . . . . 3. *A. phyllostegia.*
Androgynous spikes dense, apparently male; leaves rhombic, sinuate-dentate; bracts ovate-oblong, small; styles exserted; calyx 4-parted. California . . . 4. *A. spicata.*
Leaves oblong, entire; bracts broadly ovate or oblong; radicle nearly superior . . . . 5. *A. Alaskensis.*

* The Garden Orache, *A. hortensis*, rarely occurs escaped from cultivation, in which some of the flowers are as in *Chenopodium*, with a regular 5-lobed calyx closely covering a horizontal seed, the remainder having two broad bracts enclosing a vertical seed, without calyx.

** Leaves mostly opposite, entire.

Weak and slender; leaves long, linear; flowers axillary, androgynous; bracts linear. Vancouver's Is. . . . 6. *A. zosteræfolia.*
Erect; leaves oblong, obtuse, distant; bracts ovate-rhombic. Alaska . . . . 7. *A. Gmelini.*

SECT. II. Annuals: radicle superior (except in 8): leaves mostly alternate.

§ 3. Bracts ovate, sessile, entire and not foliaceous nor appendaged in fruit.

* Lower leaves opposite; bracts free; radicle inferior.

Flowers axillary; leaves small, crowded . . . . . 8. *A. Californica.*

** Leaves alternate; bracts united.

Flowers axillary, solitary; fruiting bracts ½″ long leaves small, entire, crowded. Nevada . . . . . 9. *A. pusilla.*
Male flowers in short spikes; pistillate solitary; fruiting bracts 1″ long, pubescent; leaves 1′ long, thin, entire. Upper Missouri . . . . 10. *A. Endolepis.*
Male flowers in interrupted spikes; pistillate very small, solitary; leaves 3–6″ long, ovate, subentire. Mexico. 11. *A. monilifera.*
Flowers axillary, clustered, staminate above; fruiting bracts 3″ long, subhastate, smooth; leaves rounded, dentate. Rocky Mountains . . . . 12. *A. Suckleyana.*

§ 4. Fruiting bracts small, oblong to cuneate-orbicular, united to above the middle, 3-nerved, rarely appendaged, the truncate or rounded apex narrowly margined and few-toothed; leaves entire.

Erect; calyx 3–4-cleft; fruiting bracts ovate-oblong, truncate, obtusely 3-toothed; leaves triangular- or cordate-ovate. Nevada . . . . 13. *A. truncata.*
Low, ascending; calyx 5-cleft; fruiting bracts ovate-oblong, truncate, entire or suberose; leaves sub-cordate-ovate. Colorado . . . . 14. *A. saccaria.*
Low, slender; fruiting bracts ovate-oblong, truncate, 3-toothed, very small; leaves linear, short. Colorado. 15. *A. Wolfii.*
Ascending; fruiting bracts sessile, broadly cuneate, sub-muricate, the rounded summit sharply 3–5-toothed; leaves oblanceolate. Atlantic coast . . . . . . 16. *A. arenaria.*
Male spikes dense; fruiting bracts very small, sessile, suborbicular, with 3–5 small teeth above; leaves ovate to oblong, sessile. California . . . . . . 17. *A. microcarpa.*
Male spikes slender; fruiting bracts broadly cuneate, pedicelled, the rounded summit sharply 5-toothed; leaves oblanceolate to linear. New Mexico . . . 18. *A. Wrightii.*

§ 5. Fruiting bracts small, axillary, cuneate-orbicular, margined above the united base and coarsely toothed, doubly tooth-crested or naked; leaves oblong to lanceolate, 1′ long or less.

Fruiting bracts broad, with equal triangular teeth, sides doubly crested; styles exserted; leaves oblanceolate, subentire, petioled . . . . 19. *A. Texana.*

Erect; fruiting bracts denticulate, not muricate; styles included; leaves lanceolate, entire. California . . 20. *A. Coulteri.*

Procumbent; fruiting bracts acuminate, unequally toothed, the sides naked or subcrested; leaves obovate, petioled, entire. California . . . . 21. *A. Barclayana.*

Suberect; fruiting bracts margined nearly to the base, 7-toothed, the middle tooth largest; styles very short; leaves undulate, sinuate. Key West . . 22. *A. cristata.*

§ 6. Fruiting bracts orbicular, 1½–2½″ broad, with a double herbaceous toothed margin, the sides carinate or rarely appendaged; leaves narrow, 1′ long or less.

* Apex of the fruiting bracts not foliaceous.

Fruiting bracts 1½″ wide, radiately toothed, not appendaged; leaves oblanceolate to linear, subdentate at the apex. New Mexico . . . . 23. *A. elegans.*

Fruiting bracts 2–2½″ wide, gash-toothed, rarely somewhat appendaged; leaves lanceolate, entire. California . . . . 24. *A. coronata.*

** Fruiting bracts tooth-crested, with an acuminate foliaceous apex; leaves lanceolate, subentire.

Flowers androgynous, axillary; fruiting bracts with a broad terminal lobe, doubly or triply tooth-crested; leaves shortly petioled. Arizona . . . . 25. *A. Powellii.*

Male flowers in a naked panicle; fruiting bracts with a narrow apex, shortly appendaged; leaves sessile. California . . . . 26. *A. bracteosa.*

§ 7. Fruiting bracts rhombic-orbicular, united, indurated, subcompressed, 2–4″ long, usually conspicuously appendaged and the foliaceous margin toothed and undulate; leaves triangular and subhastate, the lower opposite.

Male spikes short and dense; leaves petioled. Rocky Mountains . . . . 27. *A. argentea.*

Male spikes elongated, slender; leaves sessile; distantly branched. New Mexico to California . . 28. *A. expansa.*

Sect. III. Perennials, more or less shrubby, appressed-scurfy: radicle usually superior: leaves alternate.

§ 8. Fruiting bracts orbicular to ovate, toothed, usually more or less appendaged and somewhat spongy.

* Fruiting bracts slightly compressed; leaves ½–2′ long.

Erect, woody; fruiting bracts united to above the middle 2″ long or less, usually appendaged. Rocky Mountains . . . . 29. *A. Nuttallii.*

Erect, woody; bracts lanceolate, the linear apex only free, in fruit 4–6″ long and strongly crested. Arizona. 30. *A. acanthocarpa.*

Decumbent, subwoody at base; bracts axillary, ovate, 3″ long in fruit, united, usually crested, often not toothed; leaves thick, broad, obtuse. California . . 31. *A. leucophylla.*

** Leaves small, numerous; fruiting bracts more or less compressed, mostly small, cuneate-orbicular.

Tall; spikes dense, panicled; fruiting bracts compressed, toothed and usually tuberculate. Arizona . . . . 82. *A. polycarpa.*
Slender; fruiting bracts axillary or spicate, convex, toothed, usually crested; lower leaves opposite. Arizona . . . . 83. *A. Greggii.*
Fruiting bracts axillary, orbicular, compressed, toothed, 3-nerved, not appendaged; leaves mostly opposite. Mexico . . . . 84. *A. oppositifolia.*

§ 9. Tall and shrubby; spikes panicled; fruiting bracts orbicular or ovate, membranous or spongy, not appendaged nor margined; leaves ovate to rhombic, entire; radicle ascending (superior in No. 86).

Bracts rounded, compressed, united to above the middle; branches terete, unarmed. Arizona . . 85. *A. lentiformis.*
Bracts rounded, compressed, free; branches angled, spinescent. Nevada . . . . 86. *A. Torreyi.*
Bracts broadly ovate, convex, united to the middle; branches terete, unarmed. Southern California . . 87. *A. Breweri.*

§ 10. Bracts thick, scurfy, with broad rounded entire margins, not appendaged nor veined; erect, shrubby.

Bracts sessile; leaves ovate to oblanceolate, entire, subsessile. Great Basin . . . . 38. *A. confertifolia.*
Bracts shortly pedicelled; leaves rounded, sharply dentate, petioled. Arizona . . . . 39. *A. hymenelytra.*

§ 11. Shrubby; fruiting bracts united, indurated, not appendaged, with four broad membranous veined wings.

Leaves narrow; fruit 4–6″ broad. Great Basin . . . 40. *A. canescens.*

SECT. I. Annuals, somewhat succulent. Radicle inferior or somewhat ascending. Fruiting bracts herbaceous or coriaceous, free or nearly so. Flowers androgynous, or subdiœcious, in leafy or naked spikes.

§ 1. Bracts ovate-rhombic to triangular or hastate, often crested, the margin foliaceous, entire or toothed: leaves usually more or less hastate, the lowest opposite.

1. A. PATULA, Linn. Erect or decumbent, 1–4 feet high, branched, dark green and glabrous or somewhat scurfy; leaves lanceolate-hastate, 1–4 inches long, the lower on the stems and branches opposite, obtuse or acute, entire or sparingly sinuate-toothed, petioled, the upper lanceolate to linear; flowers in subdiœcious naked and usually somewhat interrupted spikes, the lower clusters axillary; fruiting bracts ovate-triangular or rhombic-hastate, compressed, united at base, becoming 3–6 lines long, obscurely 3-nerved, with a broad herbaceous entire or toothed

margin, the sides often strongly muricate; seed dark, a line broad; radicle lateral. — The typical form scarcely occurs in this country.

Atriplex patula, Linn. Hooker f., Arctic Flora, 300 and 338. Elliott, 2. 577. Torrey, Flora N.Y. 2. 137. Gray, Manual, 409. Porter, Fl. Col. 117.

Var. HASTATA, Gray. Stout, at least the lower leaves broadly triangular-hastate, entire or toothed with shallow sinuses. — The American form appears to differ from the European (*A. hastata*, Linn.) in its more usually entire leaves and greater scurfiness. Found in salt and brackish localities on the coast from New Brunswick to Virginia, and inland; from the Saskatchewan to Central Colorado, and in salt marshes near San Francisco.

Atriplex laciniata. Pursh, Flora, 199.
Atriplex laciniata, var. *Americana*. Torrey, Flora U. S. 1. 298.
Chenopodium rubrum. Hook. Fl. Bor.-Am. 2. 127, in part.
Atriplex Purshiana. Moquin, Enum. Chenop. 55; DC. Prodr. 13^2. 98. Dietrich, Syn. 5. 582.
Atriplex hastata, Linn. Engelm. Pl. Upp. Miss. 206. Gray, Pac. R. R. Rep. 12. 46. Matthew, Canad. Nat. 12. 159. Chapman, 377. Torr. Bot. Wilkes's Exp. 437.
Atriplex patula, var. *hastata*. Gray, Manual, 409.

Collectors: — James; Nuttall; Suckley; 2445 Bolander; Greene; Burgess; 259, 262 Wolf.

Var. SUBSPICATA. A low and often simple form, 3–12 inches high, usually quite scurfy; leaves lanceolate-hastate, ½–1 inch long. — From the Saskatchewan to the Missouri.

Chenopodium subspicatum. Nuttall, Genera, 1. 199. Spreng. Syst. 1. 919. Moquin, Enum. Chenop. 84.
Atriplex angustifolia. Hook. Fl. Bor.-Am. 2. 128, in part.
Atriplex laciniata, var. *Americana*. Torrey, Nicollet's Rep. 159.
Atriplex rosea. Hook. Pl. Geyer in Lond. Jour. Bot. 5. 261.
Atriplex hastata. Bourgeau, Palliser's Rep. 260.

Collectors: — Nuttall; Nicollet; Bourgeau; Hall.

Var. LITTORALIS, Gray. Slender; leaves linear-lanceolate to linear, rarely subhastate or toothed. — From New Brunswick and Canada to New York; Oregon. A narrow-leaved form rather than a variety, simulated by the upper portions of stems of var. *hastata*.

Atriplex littoralis. Bourgeau, Palliser's Rep. 260. Gray, Proc. Amer. Acad. 8. 398.
Atriplex angustifolia. Hook. & Arn. Bot. Beechey, 157?
Atriplex patula, var. *littoralis*. Gray, Manual, 409.

Collectors: — Nuttall; Kellogg; 482 Hall.

2. A. ROSEA, Linn. (Gray, Manual, 409.) Subdecumbent, grayish scurfy, 1–2 feet high; leaves ovate-rhombic to -triangular, ½–1½ inches long, sessile or very shortly petioled, sinuate-dentate, the upper ovate; spikes more leafy at base; fruiting bracts nearly as in the last, 2–3 lines broad, the margin toothed. — Of rare occurrence in the Eastern states; introduced from Europe.

§ 2. Bracts ovate to linear, mostly 4–6 lines long (small in *A. spicata*), entire and not margined nor appendaged (except in *A. phyllostegia*), only the apex foliaceous: leaves petioled.

* Leaves alternate.

3. A. PHYLLOSTEGIA. Usually stout, erect or ascending, ½–1½ feet high, simple or branched, smooth or somewhat mealy, leafy; leaves rhombic-triangular or hastate to ovate, ½–2 inches long, acute or acuminate, entire or sparingly sinuate-dentate; flowers subdiœcious, the clusters axillary and in short subnaked spikes; calyx 5-toothed or -cleft; bracts free or nearly so, linear-lanceolate, scurfy, becoming 4–6 lines long and 2 lines wide, sessile or often pedicelled, compressed, foliaceous above but somewhat coriaceous at base and strongly 3-nerved, sometimes with a sparingly laciniate marginal lobe below and occasionally with the sides herbaceously appendaged; ovary sometimes surrounded by 3 hyaline sepals half shorter than the young bracts; styles nearly equalling or shorter than the bracts; radicle ascending. — In the valleys and on the foothills of Northwestern Nevada and in Mojave Valley, Southern California, — only the latter specimens in fruit.

Obione phyllostegia. Torrey; Watson, King's Rep. 5. 291.

Collectors: — H. Engelmann; 231 Anderson; Cooper; 986 Watson; Lemmon.

4. A. SPICATA. Stout, erect, 2 feet high, diffusely branched, more or less mealy; leaves ovate-rhombic, 2 inches long, acute, cuneate to a short petiole, coarsely and irregularly sinuate-dentate; flowers androgynous in dense axillary and terminal naked closely panicled spikes, the staminate nearly concealing the fertile ones; calyx large, 4-parted; bracts ovate-oblong, 1½ lines long, free, densely farinose, herbaceous, not margined nor appendaged, apparently not much enlarged in fruit; styles long and exserted; nearly mature seed ½ of a line broad; radicle inferior. — Collected only by Brewer (1190) in San Joaquin Valley, California, east of Mt. Diablo, in alkaline soil.

5. A. ALASKENSIS. Stout, erect or ascending, a foot high or more, glabrous; leaves thick, oblong to oblong-ovate, 1½–2 inches long,

obtuse or acutish, subcuneate at base, entire, the upper linear-lanceolate and acuminate; fruiting bracts clustered in the axils, subcompressed, oblong to broadly ovate or suborbicular, 2–6 lines long, acutish or acuminate, united at base, entire, coriaceous, with a short or somewhat elongated foliaceous apex; pericarp loose and membranous; seed a line broad; radicle superior or nearly so. — Collected by Dr. A. Kellogg, at Barlow's Cove, Alaska, in fruit.

** Leaves mostly opposite, entire.

6. A. ZOSTERÆFOLIA. Weak and slender, ascending, a foot high or less, diffusely branched, glabrous or slightly scurfy; leaves fleshy, linear, 1–4 inches long, 1½ lines broad; flowers in axillary clusters and in short axillary androgynous spikes; calyx deeply 5-cleft; bracts linear, somewhat unequal, 1–2 lines becoming 4–6 lines long, free, fleshy; immature seed less than half a line broad; radicle slightly ascending; mature fruit unknown. — Collected only by Scouler at the Straits of De Fuca.

Chenopodium (?) *zosteræfolium*. Hook. Fl. Bor.-Am. 2. 127. Moquin, Enum. Chenop. 85.
Atriplex Gmelini, var. *zosteræfolia*. Moquin in DC. Prodr. 18^2. 97.

7. A. GMELINI, C. A. Meyer. Erect, slender, ½–1 foot high, subsimple, glabrous; leaves opposite, 3–5 pairs, thin, oblong, an inch long, obtuse, cuneate to a slender petiole, entire or very obscurely dentate; flowers axillary and in a short crowded terminal spike; calyx deeply 5-cleft; bracts ovate-rhombic, united at base, 1½–2½ lines long, obtuse or acute, foliaceous at the apex; seed ½ line broad; radicle inferior. — From Eschscholtz Bay to Norton Sound, and probably including all the *A. littoralis* of northern collectors. It was wrongly identified by Meyer with Gmelin's figure, which apparently concerns a narrow-leaved form of *A. patula*. Among the crowded clusters are occasionally found pistillate flowers entirely naked, with neither calyx nor bracts.

Atriplex Gmelini. C. A. Meyer, in Bong. Veg. Sitch. 160, excl. syn. Hook. Fl. Bor.-Am. 2. 128. Fenzl in Ledeb. Fl. Ross. 3. 732. Moquin, Enum. Chenop. 59; DC. Prodr. 18^2. 96. Hook f., Fl. Arc. 338. Rothrock, Fl. Alask. 455.
Atriplex angustifolia, var. *obtusa*. Chamisso in Linnæa, 6. 569.
Atriplex angustifolia. Hook. Fl. Bor.-Am. 2. 128, in part.
(?) *Atriplex littoralis*. Hook. Fl. Bor.-Am. 2. 128. Hook. & Arn. Bot. Beech. 129. Fenzl in Ledeb. Fl. Ross. 3. 729, in part. Seemann, Bot. Herald, 39. Hook. f., Fl. Arc. 300. Rothrock, Fl. Alaska, 455.

Collectors: — Bannister.

Sect. II. Annuals. Radicle superior (except in *A. Californica*). Leaves alternate or in a few species subopposite.

§ 3. Bracts ovate, sessile, united, more or less compressed, not foliaceously margined nor appendaged: flowers axillary and androgynous, or the upper clusters staminate: (bracts free and lower leaves opposite in *A. Californica*). Species not closely allied to each or any other.

8. A. Californica, Moquin. Stems a foot high, erect or decumbent at base, leafy, canescent; leaves narrowly lanceolate, 3–8 lines long, acute at each end, sessile, entire; flowers axillary; calyx 4-parted or deeply 4-cleft; bracts rhombic-ovate, becoming 1½ lines long, not indurated; styles included; seed ½ line broad. — California, by several collectors, but localities not given. Said to be perennial, though apparently annual.

Atriplex Californica. Moquin, DC. Prodr. 13^2. 98. Dietrich, Syn. 5. 584.
Collectors: — "685 Coulter;" 276 Bridges; Kellogg & Harford..

9. A. pusilla. (*Obione*, Torrey; Watson, King's Rep. 5. 291.) Slender, 2–6 inches high, diffusely much-branched, leafy, hoary-scurfy throughout; leaves broadly ovate to oblong-lanceolate, 2–4 lines long, acute, sessile, entire, mostly crowded on the branches; flowers minute, subsolitary or one of each sex in the axils; calyx deeply 5-cleft; bracts ovate, ½ line long in fruit, acutish; styles exserted; seed nearly filling the theca, the testa thin and transparent. — Northwestern Nevada, in alkaline localities (65 Anderson; 988 Watson; Gray; Lemmon).

10. A. Endolepis. Erect, 6–10 inches high, glabrous or farinose, branching from the base; leaves thin, lanceolate, an inch long, acute, sessile, entire; male clusters terminal and axillary, somewhat arachnoid, the lobes of the urceolate 5-toothed calyx strongly inflexed, with a somewhat prominent fleshy crest upon the back; pistillate flowers solitary in the lower axils, sessile; fruiting bracts ovate, a line long, membranous, pubescent; ovary surrounded by 3–4 entire or lobed hyaline sepals, which are free and much shorter than the bracts; styles slightly exserted; seed ⅔ of a line broad. — On the Upper Missouri and head-waters of the Yellowstone. The pistillate flowers escaped notice on the specimens of the earlier collectors.

Kochia dioica. Nuttall, Genera, 1. 200. Torrey, Nicollet's Rep. 158. Nees, Neuwied's Trav., Appx. 19. Moquin, Enum. Chenop. 94; DC. Prodr. 13^2. 133. Engelm. Pl. Upp. Miss. 206.
Salsola dioica. Sprengel, Syst. 1. 923. Dietr. Syn. 2. 996.
Endolepis Suckleyana. Torrey, Pac. R. R. Rep. 12. 47, t. 8.
Collectors: — Nicollet; Fremont; Suckley; Allen; Gray; Parry.

11. A. MONILIFERA. Low, slender, branching from the base, the stems decumbent or ascending, 3–6 inches long, leafy, hoary-farinose; leaves broadly ovate to lanceolate, 3–6 lines long, acute, obtuse or cordate at base, sessile, entire or somewhat repand-dentate; male flowers in dense globose clusters, mostly in terminal naked subpanicled spikes, the calyx 5-cleft to the middle; flowering bracts minute, solitary in the axils, ovate, acute, entire, enclosing two shorter sepals alternate with them; styles exserted; mature fruit unknown. — Collected by Dr. Gregg in the dried bed of a lake in Bolson de Mapimi, Chihuahua; "Quelito," used for greens.

12. A. SUCKLEYANA. Prostrate or ascending, the stems a foot long or more, stout and somewhat fleshy, smooth or coarsely scurfy, leafy; leaves suborbicular to ovate or rhombic, ½–1 inch long, obtuse, abruptly narrowed into a slender petiole exceeding the blade, acutely repand-dentate; flowers in axillary clusters, the staminate above; calyx 3–4-parted to the base; fruiting bracts 2½–3 lines long, ovate-rhombic and subhastate, flattened, surrounded by a very narrow crenate-denticulate margin; seed large, filling the cavity, the testa very thin. — From Milk River, Northern Montana, to South Park, Colorado.

Obione Suckleyana. Torrey, Pac. R. R. Rep. 12. 47, t. 4. Engelm. Pl. Upp. Miss. 206. Porter, Fl. Col. 118.

Collectors: — Suckley; Hayden; Meehan.

§ 4. Fruiting bracts 1–2 lines long or less, oblong to cuneate-orbicular, united to above the middle, coriaceous or somewhat indurated, only the truncate or rounded apex narrowly margined and few-toothed, the sides 3-nerved, rarely appendaged: spikes leafy or the staminate naked and slender (in *A. microcarpa* and *Wrightii*): leaves entire.

13. A. TRUNCATA, Gray. Rather stout, erect and mostly strict, 1–3 feet high, sparingly branched, leafy, canescent, scurfy above; leaves broadly ovate, ½–1½ inches long, truncate or cordate at base, acute, sessile or the lower shortly petioled; spikes more or less leafy; calyx mostly 3–4-parted; fruiting bracts 1½ lines long, ovate-oblong, sessile or shortly pedicelled, united up to the truncate herbaceous summit, which is obtusely 3-toothed, the sides rarely subtuberculate. — Frequent from Oregon to Northwestern Nevada.

Atriplex patula, var. Hook. Fl. Bor.-Am. 2. 128.
Atriplex patula. Newberry, Pac. R. R. Rep. 6. 87.
Obione truncata. Torrey; Watson, King's Rep. 5. 271.
Atriplex truncata. Gray, Proc. Amer. Acad. 8. 398.

Collectors: — 228 Stretch; 40 Anderson; Newberry; 987 Watson; Gray; 483 Hall.

14. A. SACCARIA. Ascending, 3–5 inches high, diffusely branched, leafy, densely scurfy; leaves very broadly ovate, ½ inch long, subcordate at base, acute, very shortly petioled or sessile; flowers axillary; calyx 5-cleft to the middle; fruiting bracts nearly as in the last, but not at all appendaged, pedicelled and often deflexed, the truncate summit entire or suberose. — Collected by Dr. A. Gray in 1872, on the desert plains of Southern Wyoming or Northern Utah.

15. A. WOLFII. Low, slender, 6 inches high, branching from the base, scurfy-canescent and reddish; leaves linear, 4–6 lines long, acute, sessile; flowers very small, in androgynous axillary clusters; calyx deeply 5-cleft; fruiting bracts as in *A. truncata*, ½–¾ line long, sessile, the herbaceous summit somewhat broader than the body, with a quadrilateral tooth on each side and a small acute tooth in the centre; styles very short. — Collected by Mr. Wolf, upon Lt. Wheeler's survey, on alkaline flats at Saguache, Central Colorado.

16. A. ARENARIA, Nutt. Ascending, ½–1 foot high or more, diffusely branched, leafy, silvery-mealy; leaves thin, oblanceolate, ¾–1½ inches long, acute or obtuse, attenuate to a short petiole; flowers axillary, androgynous; fruiting bracts sessile, broadly cuneate, 1½–3 lines broad, acutely 3–5-toothed at the rounded herbaceous summit, the sides strongly reticulated and not appendaged, or with 2–3 hooked projections, or more rarely doubly crested. — On the seacoast from Nova Scotia to Key West.

Atriplex arenaria. Nuttall, Genera, 1. 198. Spreng. Syst. 1. 918. Dietrich, Syn. 5. 535. Gray, Manual, 409.

Obione arenaria. Moquin, Enum. Chenop. 71; DC. Prodr. 13^2. 107. Torrey, Flora N. Y. 2. 138. Chapman, 377. Smith, Proc. Acad. Phil., 1867, 22. Matthew, Canad. Nat. 12. 159.

17. A. MICROCARPA, Dietrich. Slender, ½–1 foot high, "procumbent" or erect, somewhat branched, leafy, canescent; leaves ovate to oblong, 3–5 lines long, obtuse or acutish, cuneate at base, sessile; flowers in small axillary clusters, the staminate dense and mostly terminal; calyx deeply 5-cleft; fruiting bracts but half a line broad, orbicular or obovate, sessile, the summit narrowly margined with 3–5 small herbaceous teeth, the sides naked or minutely bi-tuberculate; styles short. — San Diego, California; collected by Barclay and Newberry. Mr. Bentham has published a second *A. microcarpa* in Fl. Australiensis, 5. 176.

Obione microcarpa. Benth. Bot. Sulphur, 48. Moquin, DC. Prodr. 13^2. 111. Walpers, Ann. 1. 567.

Atriplex microcarpa. Dietrich, Syn. 5. 536.

Obione arenaria? Torrey, Ives's Rep. 25. Hook. & Arn. Bot. Beechey, 157?

18. A. WRIGHTII. Slender, erect, a foot high, simple or sparingly branched, leafy below, glaucous-mealy; leaves oblanceolate to linear, ½–1 inch long, 3–4 lines long upon the branches, acute or the lower obtuse; male flowers in naked terminal spikes; fruiting bracts axillary, a line long, broadly cuneate upon a short pedicel, acutely 5-toothed at the rounded summit, the sides reticulated, with rarely 1–2 straight projections. — New Mexico (1743 Wright) and Arizona (Palmer).

Obione elegans, var. (?) *radiata*. Torrey, Bot. Mex. Bound. 188, in part.

§ 5. Fruiting bracts 1½ lines long or less, axillary, cuneate-orbicular, subindurated, united at base, herbaceously margined above and coarsely toothed, the sides doubly tooth-crested or naked: leaves thin, oblong to lanceolate, an inch long or less: male clusters subterminal or in slender naked spikes: grayish puberulent.

19. A. TEXANA. Erect or ascending, ½–1½ feet high, slender, branched; leaves oblanceolate, 1 inch long, acute, attenuate to a slender petiole, sparingly dentate or entire; male clusters subterminal; calyx 5-cleft; fruiting bracts 1½ lines long, broadly cuneate, the upper portion margined with several nearly equal triangular subdenticulate teeth, the sides reticulated and crested with a double row of acute teeth; styles elongated and exserted. — Western Texas.

Obione elegans, var. *tuberculata*. Torrey, Bot. Mex. Bound. 188.
Collectors: — Wright; Schott; cult. hort. Camb.

20. A. COULTERI, Dietrich. "Fruticose" (?), erect, 1–2 feet high, slender, branched; leaves lanceolate, 4–6 lines long, ½–1 line broad, attenuate at each end, acute and mucronate, subundulate, entire; fruit sessile, a line long, with a narrow denticulate margin from near the base, the sides obsoletely nerved, not appendaged; styles not exserted. — California; collected only by Coulter.

Obione Coulteri. Moquin, DC. Prodr. 13^2. 118.
Atriplex Coulteri. Dietrich, Syn. 5. 537.

21. A. BARCLAYANA, Dietrich. Slender, with long procumbent branches; leaves obovate, 8–12 lines long, 4–5 lines broad, obtuse, the upper oblong and acutish, mucronulate, long-petioled, entire, subcoriaceous; fruiting bracts scarcely a line broad, sessile, unequally 8–10 toothed above, the terminal tooth largest, the sides naked or obsoletely nerved or slightly doubly tooth-crested. — Known only from a specimen in the Hooker herbarium, collected by Hinds at Magdalena Bay.

Obione Barclayana. Benth. Bot. Sulph. 48. Walpers, Ann. 1. 567. Moquin, DC. Prodr. 13^2. 112.
Atriplex Barclayana. Dietrich, Syn. 5. 537.

22. A. CRISTATA, HBK. Slender, decumbent or ascending, 1–1½ feet high, branching, leafy; leaves oblanceolate to obovate, ½–1 inch long, usually obtuse, mucronulate and undulate, sinuate-dentate or the upper entire; flowers axillary or the male often in naked slender terminal spikes; fruiting bracts 1½ lines long, margined nearly to the base, the terminal tooth most prominent, with three smaller on each side; styles very short, included.—Tropical America and the West Indies; Key West, collected only by Blodgett. Said to be perennial and sometimes becoming woody at base, but the Floridan specimens appear to be annual.

Atriplex cristata. HBK., Nov. Gen. & Sp. 2. 192.
Obione cristata. Moquin, Enum. Chenop. 78; DC. Prodr. 18^2. 110. Chapman, 377.

§ 6. Fruiting bracts united, orbicular, compressed, indurated, 1½–2½ lines broad, surrounded by a double herbaceous toothed margin, the sides carinate, usually not appendaged: flowers mostly axillary: leaves narrow, an inch long or less.

* Apex of fruiting bracts not foliaceous.

23. A. ELEGANS, Dietrich. Erect, slender, ½–1 foot high, branching, leafy; leaves oblanceolate to linear, 6–9 lines long, obtuse or acute, entire or with a few teeth near the apex; fruiting bracts 1½ lines broad, very shortly pedicelled, the margins sharply and radiately toothed, the sides more or less prominently carinate, not appendaged. —New Mexico and Arizona to Northern Mexico.

Obione elegans. Moquin, DC. Prodr. 18^2. 118.
Atriplex elegans. Dietrich, Syn. 5. 537.
Obione radiata. Torrey, Bot. Mex. Bound. 183.
Obione elegans, var. (?) *radiata.* Torrey, Bot. Mex. Bound. 183, in part.
Collectors:—1875 Coulter; 571 Wright; 715 Thurber; 219 Palmer.

24. A. CORONATA. Stout, becoming woody at base, erect, 1–2 feet high, branched, leafy, hoary-farinose; leaves lanceolate, ½–1 inch long, attenuate to the base or to a short petiole, acute, entire; flowers minute; calyx 5-cleft; fruiting bracts 2–2½ lines long, the margins gash-toothed, the sides rarely slightly tuberculate.—San Joaquin Valley, California, in alkaline soil (1189 Brewer), and near Fort Mojave (Cooper).

** Fruit 1–2 lines long, with a foliaceous acuminate apex and the sides tooth-crested: leaves lanceolate, entire or subdenticulate.

25. A. POWELLII. Erect, slender, 1–2 feet high, branched, leafy, grayish; leaves ½–1 inch long, acuminate, attenuate to a short petiole,

the upper sessile and abruptly rounded at base; flowers androgynous; calyx very small, 5-cleft; bracts 1½–2 lines long, united below, panduriform, the terminal lobe entire, the margin below it gash-toothed, the sides doubly or triply tooth-crested; styles short; seed not filling the theca. — Cultivated from Arizona seeds; fruit collected by the Indians for food.

26. A. BRACTEOSA. (*Obione*, Durand & Hilgard, Pacific R. R. Rep. 5. 13, t. 14.) Erect, "2–3 feet high," branched, leafy, hoary-farinose; leaves ½–1 inch long, rather thin, acuminate, sessile; male flowers in dense globose clusters in a naked terminal panicle, the calyx deeply 5-cleft; fruiting bracts 1½ lines long, in small axillary clusters, orbicular with a short cuneate base, the terminal lobe linear or lanceolate, margins irregularly gash-toothed and the sides shortly muricate. — Collected only by Heermann on Posé Creek, California.

§ 7. Fruiting bracts rhombic-orbicular, subcompressed, 2–4 lines long, indurated, closed, usually strongly muricate and with a herbaceous toothed and undulate margin: male flowers mostly in terminal spikes: leaves triangular and subhastate, the lower opposite.

27. A. ARGENTEA, Nutt. Erect, ascending, or decumbent, ½–1½ feet high, diffusely branched and leafy, grayish scurfy or nearly glabrous; leaves rather thick, deltoid or triangular-ovate or subrhombic, often subhastate, ½–2 inches long, acute or obtuse, petioled or the upper sessile; calyx deeply 5-cleft; fruiting bracts shortly pedicelled, united nearly or quite to the apex, the more or less dilated free margins extending nearly to the base, often parted at the apex, more or less acutely and deeply toothed, the sides usually appendaged with herbaceously tipped projections or with a double toothed crest. — From the Upper Missouri to Colorado and North Eastern California. A variable species.

Atriplex argentea. Nuttall, Genera, 1. 198. James, Catalogue, 178. Spreng. Syst. 1. 918. Dietrich, Syn. 5. 588. Torrey, Ann. N.Y. Lyc. 2. 240. Coulter, Hayden's Rep., 1872, 779.

Obione (?) *argentea.* Moquin, Enum. Chenop. 76; DC. Prodr. 13². 115. Torrey, Nicollet's Rep. 158. Engelmann, Pl. Upp. Miss. 206. Newberry, Pac. R. R. Rep. 6. 87. Gray, Pac. R. R. Rep. 12. 47; Proc. Philad. Acad., 1868, 75. Porter, Hayden's Rep., 1870, 481; Fl. Col. 117. Watson, King's Rep. 5. 290.

Atriplex arenaria. Hook. Pl. Geyer in Lond. Jour. Bot. 5. 261 ?

Collectors: — Nicollet; 97, 621 Fremont; Suckley; 484 Hall & Harbour; 985 Watson; Vasey; Hayden; Gray; Greene; Allen.

28. A. EXPANSA. Resembling the last, but stouter, erect, more divaricately and distantly branched, with thinner triangular subhastate leaves, sessile or very nearly so, the terminal staminate spikes usually slender and leafless toward the apex, interrupted. — From New Mexico and Southern Colorado to Southern California. Described by Mr. Wright as growing in the bottoms of the Rio Grande in intricately entangled masses 6–10 feet in diameter and 4–6 feet high.

Obione argentea. Torrey, Emory's Rep. 149; Pac. R. R. Rep. 2. 178; Bot. Mex. Bound. 182.

Collectors: — 708 Fendler; 574 Wright; Emory; Bigelow; 460 Torrey; Greene.

Sect. III. Perennials, more or less shrubby, closely appressed scurfy, mostly diœcious. Radicle usually superior. Leaves mostly alternate.

§ 8. Fruiting bracts orbicular to ovate, with a toothed margin and the sides usually more or less appendaged, somewhat spongy: flowers axillary or spicate.

* Fruiting bracts rather large, slightly compressed: leaves over half an inch long, alternate.

29. A. NUTTALLII. Erect, 1–2 feet high, branching mostly from the base; leaves narrowly oblong or oblanceolate, ½–2 inches long, obtuse or acutish, narrowed at base, sessile, entire; calyx 5-cleft; bracts ovate, united to above the middle, the orifice scarcely contracted, mostly sessile, becoming suborbicular and 1½–2 lines long, not compressed, the margin and summit irregularly gash-toothed and the sides usually muricate or tooth-crested. — From the Saskatchewan to Colorado and Northern Nevada.

Atriplex canescens. Nuttall, Genera, 1. 197; not of James. Spreng. Syst. 1. 961. Hook. Fl. Bor.-Am. 2. 128; Pl. Geyer, Lond. Jour. Bot. 5. 261 (?) Dietr. Syn. 5. 537. Bourgeau, Palliser's Rep. 260. Porter, Hayden's Rep., 1871, 492.

Obione canescens. Moquin, Enum. Chenop. 74; DC. Prodr. 18^2. 112. Torrey, Nicollet's Rep. 158; Fremont's Rep. 95, in part; Stansbury's Rep. 395, in part. Durand, Fl. Utah, 174, in part. Engelm. Pl. Upp. Miss. 206? Cooper, Pac. R. R. Rep. 12. 47? Gray, Proc. Phil. Acad., 1863, 75. Watson, King's Rep. 5. 289, in part. Coulter, Hayden's Rep., 1872, 779? Porter, Fl. Col. 117.

Atriplex Gordoni. Hook. Pl. Geyer in Lond. Jour. Bot. 5. 261?

Collectors: — Richardson; Nicollet; Fremont; Burke; Bourgeau; Stansbury; 308 Hall & Harbour; 981 Watson; Canby; Gray; Hayden; Burgess.

30. A. ACANTHOCARPA. (*Obione*, Torrey, Bot. Mex. Bound. 183, mostly.) Erect, 1–2 feet high or more, branched, leafy; leaves oblong-lanceolate or oblanceolate, often subhastate, ½–1½ inches long, acute or acutish, cuneate to a short petiole, usually undulate, sinuately toothed or entire; flowers diœcious, the male clusters dense in naked terminal panicled spikes; calyx 5-cleft; fertile clusters axillary, few-flowered; bracts sessile or pedicelled, lanceolate, the linear apex only free, becoming thick and spongy and 4–6 lines long, the margins gash-toothed and the sides strongly appendaged with rigid flattened processes; seed a line long, filling the cavity. — From the Rio Grande Valley to Sonora; collected by Gregg (459) and Wright (573, 1739).

31. A. LEUCOPHYLLA, Dietrich. Stems decumbent or ascending, stout, hardened at base, leafy; leaves thick, obovate or orbicular to elliptical, ½–1½ inches long, obtuse or acutish, cuneate at base, sessile, entire; flowers in loose axillary clusters; calyx large, 5-cleft; bracts sessile, ovate, united, becoming 2½–3½ lines long and spongy, the tips free, margin entire or somewhat toothed, the sides usually tuberculately crested; seed 1½ lines long. — On the seashore from San Francisco to Santa Barbara, California.

Obione leucophylla. Moquin, DC. Prodr. 13^2. 109. Benth. Pl. Hartw. 332. Bolander, Catalogue, 25. Torr. Bot. Wilkes's Exp. 437.

Atriplex leucophylla. Dietrich, Syn. 5. 536.

Collectors: — Chamisso; 1934 Hartweg; Wilkes; 425 Bolander; 309 Brewer; Kellogg & Harford.

** Fruiting bracts more or less compressed, mostly small: leaves numerous, about 3 lines long or less, entire, more or less opposite in *A. Greggii* and *oppositifolia*.

32. A. POLYCARPA. Erect, 2–3 feet high, diffusely much branched, the branches terete, slender, rigid, leafy; leaves thick, mostly minute, ½–3 lines long, obovate to spatulate, obtuse, cuneate at base, sessile; flowers in dense paniculate naked spikes; calyx deeply 5-cleft; bracts sessile, free, compressed, cuneate-orbicular, becoming 1–1½ lines broad, spongy and not at all indurated, the entire margin above the base finely gash-toothed or sharply dentate, the sides usually more or less prominently tuberculate; styles short; pericarp loose; seed ½ line broad, the radical highly lateral. — From Fort Mojave eastward through Arizona.

Obione polycarpa. Torrey, Emory's Rep. 150; Pac. R. R. Rep. 4. 130; Ives's Rep. 25.

Collectors: — Emory; Bigelow; Cooper; Palmer.

33. A. GREGGII. Slender, 6–15 inches high, leafy; leaves alternate or the lower opposite, oblong or spatulate, 3–6 lines long, obtuse or acutish, cuneate at base, mostly sessile; flowers in small axillary clusters or slender interrupted nearly naked spikes; calyx 5-cleft; bracts united only at base, cuneate-orbicular, becoming 1½–3 lines broad, margined from below the middle, the margin dentate and the convex sides usually tooth crested. — New Mexico to Sonora.

Obione canescens, var. Torrey, Bot. Mex. Bound. 183.
Obione acanthocarpa. Torrey, Bot. Mex. Bound. 183, in part.
Collectors: — 1846 Berlandier; 462 Gregg; Emory; Thurber; Bigelow; 572, 1187, 1188 Wright.

34. A. OPPOSITIFOLIA. Woody at base and apparently perennial, erect, 1 foot high, strict, branched, leafy; leaves thick, 1–2 lines long, nearly equalling or exceeding the nodes, mostly opposite, oblong-lanceolate, acutish, sessile and broadest at base; flowers axillary, sessile, diœcious (?); fruiting bracts united, orbicular, a line broad, shortly pedicelled, the margin radiately toothed, sides 3-nerved, not appendaged. — In the Rio Grande Valley on the Mexican side, collected only by Berlandier (No. 3201, "Matamoras to San Fernando").

§ 9. Fruiting bracts orbicular or ovate, membranous or spongy and not at all herbaceous, free or partly united, 1–2 lines broad, not margined nor appendaged, more or less compressed, nearly entire: radicle ascending (superior in *A. Torreyi*): leaves alternate, entire, ovate to rhombic or subhastate: tall and shrubby, diœcious, the flowers in naked axillary and terminal panicled spikes.

35. A. LENTIFORMIS. Diffusely branched, 2–12 feet high, the branches terete, unarmed; leaves ovate- to oblong-rhombic or subhastate, ½–1½ inches long, cuneate at base; calyx 5-parted; bracts strongly compressed, united to above the middle, the circular free margins obscurely crenate; styles short; seed ⅔ of a line broad, dark. — Southern California (Posé Creek and Ft. Yuma) and eastward through Arizona.

Obione lentiformis. Torrey, Sitgreave's Rep. 169, t. 14 (and Flora, 38. 362); Pac. R. R. Rep. 4. 129.
Obione Barclayana. Dur. & Hilg. Pac. R. R. Rep. 5. 13; not of Benth. Torrey, Ives's Rep. 25.
Obione acanthocarpa, var. (?) Torrey, Bot. Mex. Bound. 183.
Collectors: — Woodhouse; Emory; Bigelow; Heermann; Thomas; Palmer.

36. A. Torreyi. (*Obione*, Watson, King's Rep. 5. 290.) Diffusely and rigidly branched, 2–5 feet high, the leafy branches strongly angled, the branchlets divaricate and spinescent, bluish gray; leaves ovate- to oblong-triangular, or subhastate, ½–1 inch long; spikes dense; calyx deeply 4-cleft; bracts orbicular to reniform, free, strongly compressed, obscurely denticulate; styles short; seed ¾ of a line broad, light colored; radicle superior and projecting.—East of the Sierra Nevada in the desert valleys of Nevada and on the Mojave.

Collectors: — 463 Torrey; 984 Watson; Cooper; Burgess.

37. A. Breweri. Tall, 6 feet high or more, grayish, the branches terete, unarmed, leafy; leaves ovate or subdeltoid, 1–2 inches long, cuneate at base; flowers mostly diœcious; calyx deeply 4-cleft; fruiting bracts ovate to orbicular, convex, united at the margin to the middle, entire, scarcely over a line long; styles short; seed ¾ of a line long, subcompressed, with a loose and somewhat thickened pericarp. — On the seashore at Santa Monica and Santa Barbara, California.

Collectors: — Fremont; 459 Torrey; 75 Brewer.

§ 10. Bracts thick and scurfy, ½ inch broad, with suborbicular free entire margins, not veined nor appendaged: flowers spicate or axillary: leaves alternate: erect diffusely branched shrubs, leafy and very scurfy.

38. A. confertifolia. 1–5 feet high, subspinescent; leaves ovate or obovate to oblanceolate, 2–8 lines long, obtuse or acutish, cuneate at base, sessile or shortly petioled, entire; flowers in small axillary clusters; calyx 5-cleft; bracts sessile, united at the cuneate base around the seed and broadly margined above; seed a line broad, filling the cavity. — Abundant in alkaline valleys throughout the Great Basin, from Southern Idaho and Wyoming to New Mexico and Northern Mexico.

Obione confertifolia. Torrey, Fremont's Rep. 318 (and Bot. Zeit. 5. 57; Walpers's Ann. 1. 567); Stansbury's Rep. 395; Pac. R. R. Rep. 2. 173; Bot. Mex. Bound. 183; Ives's Rep. 25. Durand, Fl. Utah, 174. Watson, King's Rep. 5. 289. Coulter, Hayden's Rep., 1872, 779.
Obione spinosa. Moquin, DC. Prodr. 13^2. 108. Engelm. Pl. Upp. Miss. 206.
Atriplex spinosa. Dietrich, Syn. 5. 536.

Collectors: — 24, 761, 767 Fremont; Stansbury; 253 Stretch; 468 Torrey; Bigelow; Palmer; 2884 Brewer; 983 Watson; H. Engelmann; Gray; 862 Kellogg & Harford; Allen.

39. A. hymenelytra. Two to three feet high; leaves deltoid, orbicular, or rhombic, ½–1 inch in diameter, truncate or cuneate at

base, petioled, coarsely and acutely dentate; flowers axillary or paniculately spicate; calyx large, 5-parted nearly to the base; fruiting bracts shortly pedicelled, the wing-like reniform margin submembranous; styles elongated, exserted; seed a line broad. — In alkaline plains from Southeastern California to Southern Utah.

Obione hymenelytra. Torrey, Pac. R. R. Rep. 4. 129, t. 20; Bot. Mex. Bound. 182; Ives's Rep. 25. Anderson, Fl. Nevada, 125. Watson, King's Rep. 5. 290.

Collectors: — Fremont; Emory; Bigelow; Schott; Wheeler.

§ 11. Fruiting bracts indurated, not scurfy, united to the apex, not muricately appendaged, with four broad wings, distinct and not evidently marginal, membranous, veined, entire or toothed: leaves narrow, entire, the lower often opposite: an erect diffusely branched shrub, monœcious or diœcious.

40. A. CANESCENS, James. One to two feet high; leaves narrowly oblong or oblanceolate, ½–2 inches long, obtuse or acutish, narrowed at base, sessile; flowers axillary or in naked spikes; calyx 5-cleft; bracts at first ovate, adherent below to the pedicel of the ovary and contracted above to a very narrow orifice, subcompressed in fruit and more or less pedicelled, the wings 4–6 lines in diameter and extending above the narrow toothed apex; seed ovate, ¾–1 line long. — From Colorado to Northern Nevada, and southward to New Mexico, Northern Mexico, and Southern California. Has been often confounded with *A. Nuttallii.*

Calligonum canescens. Pursh, Flora, 370.

Atriplex canescens. James, Catalogue, 178. Torrey, Ann. N.Y. Lyc. 2. 239.

Pterochiton occidentale. Torrey, Fremont's Rep. 318 (and Bot. Zeit. 5. 57; Walpers, Ann. 1. 567).

Pterochiton canescens. Nuttall, Pl. Gambel. in Jour. Acad. Phil. 1. 184.

Obione tetraptera. Benth. Bot. Sulphur, 48 (and Walpers, Ann. 1. 567).

Obione canescens. Torrey, Fremont's Rep. 95, in part; Emory's Rep. 411; Sitgreave's Rep. 169; Marcy's Rep. 296; Stansbury's Rep. 395, in part; Pac. R. R. Rep. 4. 7 and 130; same, 7. 18 (?); Bot. Mex. Bound. 182, and 183 in part; Ives's Rep. 25. Torr. & Gray, Pac. R. R. Rep. 2. 173 (?) Durand, Fl. Utah, 174, in part. Watson, King's Rep. 5. 289, in part.

Obione occidentalis. Moquin, DC. Prodr. 13^2. 112. Dur. & Hilg. Pac. R. R. Rep. 5. 13. Torrey, Bot. Mex. Bound. 184.

Atriplex Berlandieri. Moquin, Enum. Chenop. 65. Dietrich, Syn. 5. 537.

Obione Berlandieri. Moquin, DC. Prodr. 13^2. 114.

Atriplex occidentalis. Dietrich, Syn. 5. 537.

Collectors: — James; 45, 94, 204, 211, 433 Fremont; 190, 191, 1347, 1450 Berlandier; 348, 575, 1740, 1741 Wright; 522 Gregg; 709 Fendler; Emory; Abert; Marcy; Stansbury; 139 Bigelow; Parry; Cooper; 982 Watson; 487, 488 Vasey; 861 Kellogg & Harford; 343 Greene; Thompson.

Var. ANGUSTIFOLIA. Leaves linear, often more or less revolute.

Obione occidentalis, var. *angustifolia*. Torrey, Bot. Mex. Bound. 184.
Collectors:—Gregg; Edwards; 576, 1742 Wright.

13. EUROTIA, Adanson.

Flowers diœcious or monœcious. Male flowers bractless, the calyx 4-parted with unappendaged lobes and as many stamens; filaments slender, exserted. Pistillate flowers without calyx, bibracteate. Bracts sessile, somewhat obcompressed, united to the apex, becoming enlarged and rather rigidly membranous, not winged, 2-horned at the apex, the sides densely covered with long spreading tufted hairs. Ovary oblong-ovate, sessile, hairy, firmly membranous: styles 2, exserted, somewhat hairy. Seed vertical, obovate, the testa simple: cotyledons broad and green; radicle inferior.—Low pubescent undershrubs, with alternate entire leaves, and small clustered axillary and subspicate flowers.

1. E. LANATA, Moquin. White-tomentose throughout with stellate hairs (becoming rufous), ½–1½ feet high, erect, with strict ascending leafy branches; leaves linear to narrowly lanceolate, with revolute margins, ½–1½ inches long, obtuse; calyx-lobes ovate, acute, hairy; bracts lanceolate, 2–3 lines long in fruit, with two short horns at the apex, penicillate with four dense spreading tufts of silvery-white hairs; utricle filling the theca and loosely enveloping the seed, which is 1½ lines long.—From the Saskatchewan to New Mexico, and westward to the Sierra Nevada; a valuable forage-plant. Quite distinct from *E. ceratoides* of the Old World.

Diotis lanata. Pursh, 602. Nuttall, Genera, 2. 207. James, Catalogue, 189. Spreng. Syst. 3. 836.

Eurotia ceratoides. Hook. Fl. Bor.-Am. 2. 126; not Mey. Bourgeau, Palliser's Rep. 260. Torr. Bot. Wilkes's Exp. 438.

Eurotia lanata. Moquin, Enum. Chenop. 81; DC. Prodr. 13². 121. Torrey, Fremont's Rep. 95; Emory's Rep. 149 and 409; Pac. R. R. Rep. 2. 124 and 4. 130; Bot. Mex. Bound. 184. Engelm. Pl. Upp. Miss. 206. Gray, Pac. R. R. Rep. 12. 47; Am. Jour. Sci. 2. 34. 258. Watson, King's Rep. 5. 292. Coulter, Hayden's Rep., 1872, 779. Porter, Fl. Col. 118.

Collectors:—James; Drummond; Nicollet; 42, 440 Fremont; 1838 Berlandier; 713, 714 Fendler; 579, 1744 Wright; Abert; Emory; 107 Geyer; 81 Beckwith; H. Engelmann; 328 Parry; Bourgeau; 990 Watson; 866 Vasey; 857 Kell. & Harford; Hayden.

14. GRAYIA, Hook. & Arn.

Flowers diœcious or sometimes monœcious. Calyx of the bractless staminate flowers mostly 4-parted, the 4–5 stamens central, with short

subulate filaments. Pistillate flowers without calyx, enveloped in the strongly obcompressed membranous bracts, which are united into an orbicular flattened sac, with a small naked orifice at the apex, adherent below to each other and to the pedicel of the ovary, becoming enlarged, reticulately veined and somewhat wing-margined vertically. Ovary narrowly ovate-oblong: styles 2, slender, at first exserted. Pericarp thin and membranous, orbicular. Seed vertical, with a simple membranous testa; embryo annular; radicle inferior. — A subspinescent undershrub, with alternate entire leaves, the small flowers in axillary clusters or terminal spikes.

1. G. POLYGALOIDES, Hook. & Arn. Erect, diffusely branched, 1–3 feet high, the branchlets frequently spinescent; leaves rather fleshy, glabrous or at first with the young branches somewhat mealy, oblanceolate, spatulate, or obovate, 6–15 lines long, obtuse or acute, narrowed at base and sometimes petioled; male flowers in axillary clusters, the pistillate mostly spicate; fruiting perianth 3–6 lines in diameter, sessile, smooth, emarginate, thin, white or pinkish, the seed usually central, about ⅔ of a line broad. — Frequent throughout the Great Basin in alkaline soils, from the Columbia to Utah and South-eastern California.

Chenopodium (?) *spinosum*. Hook. Fl. Bor.-Am. 2. 127. Moquin, Enum. Chenop. 84.

Grayia polygaloides. Hook. & Arn. Bot. Beechey, 387. Hook. Icones, t. 271; Pl. Geyer, Lond. Jour. Bot. 5. 262. Torrey, Fremont's Rep. 319; Stansbury's Rep. 394; Bot. Wilkes's Exp. 437. Torr. & Gray, Pac. R. R. Rep. 2. 124. Durand, Fl. Utah, 174. Anderson, Cat. Fl. Nevada, 125. Watson, King's Rep. 5. 292. Coulter, Hayden's Rep., 1872, 779.

Grayia spinosa. Moquin, DC. Prodr. 13^2. 119.

Collectors: — Tolmie; Fremont; Stansbury; 802 Wilkes; 30 Beckwith; H. Engelmann; 114, 166 Stretch; 277 Anderson; 989 Watson; 858 Kellogg & Harford; Gray.

15. CORISPERMUM, A. Juss.

Flowers perfect, ebracteate. Calyx 1- (rarely 2–3-) sepaled, hyaline, or none; sepals ovate to suborbicular, erose or lacerate at the apex. Stamens 1–5, hypogynous, one longer. Ovary ovate: styles 2. Fruit (caryopsis) elliptic, vertical, plano- or concavo-convex, the margin acute or narrowly winged, the membranous pericarp closely adherent to the seed. Embryo green, slender, surrounding the copious sub-fleshy albumen; radicle inferior. — Annual herbs, with alternate sessile linear leaves, the flowers spicate, solitary in the axils of reduced leaves.

1. C. HYSSOPIFOLIUM, Linn. More or less floccose- or villous-pubescent, erect, ½–1½ feet high, diffusely branched; leaves ¾–1½ inches long, 1–2 lines wide, cuspidate, the floral bracts reduced more or less abruptly from linear-lanceolate to ovate, acute or acuminate, membranously margined; sepals rarely wanting; shorter stamens more or less perfectly developed; fruit 1½–2 lines long, narrowly winged, obtuse, often mucronate with the projecting styles. — From the Arctic Ocean to the Great Lakes and the Missouri River, to New Mexico, Chihuahua, and the Columbia. Quite variable, but none of the differences seem specific.

Corispermum hyssopifolium, Linn. Pall. Fl. Ross. 2. 112, t. 98. Pursh, Flora, 4. James, Catalogue, 172. Hook. Fl. Bor.-Am. 2. 125. Torrey, Sitgreave's Rep. 170; Pac. R. R. Rep. 4. 130; Bot. Mex. Bound. 184; Ives's Rep. 25. Seemann, Bot. Herald, 53. Engelm. Pl. Upp. Miss. 206. Hook. Pl. Geyer in Lond. Jour. Bot. 5. 261. Hook. f., Pl. Arc. 300. Bourgeau, Palliser's Rep. 260. Rothrock, Fl. Alaska, 455. Watson, King's Rep. 5. 293. Gray, Manual, 409. Torr. Bot. Wilkes's Exp. 438.

Corispermum hyssopifolium, var. *Americanum*. Nuttall, Genera, 1. 4. Torrey, Ann. N.Y. Lyc. 2. 240.

Corispermum Americanum. Nuttall, Fl. Arkansas, 165.

Collectors: — Drummond; Wilkes; Wright; Parry; H. Engelmann; Bourgeau; Hall; Clinton; Lapham; Scammon; 998 Watson; Vasey; 37 Wolf.

Var. MICROCARPUM. Spikes slender, elongated; fruit a line long. — New Mexico.

Collectors: — 711 Fendler; 580, 1170 Wright; Palmer.

16. SALICORNIA, Tourn.

Flowers mostly perfect, deeply immersed by threes in the rachis of a jointed spike, decussately opposite in the axils of cupshaped bracts, the lateral ones of each cluster lower and often staminate. Calyx a fleshy rhomboidal sac with thickened margin, and an anterior opening, enclosing the flower and fruit, adherent by a narrow line to the rachis, and becoming thickened and spongy in fruit, deciduous. Stamens 1–2, with large oblong anthers on short filaments, at length exserted. Ovary oblong, posterior to the axis of the flower: styles 2–3, short, free. Pericarp adherent to the seed, membranous. Seed vertical, obovate-oblong, escaping through the thin base of the calyx; albumen very small and lateral; embryo conduplicate, thick, green, the radicle inferior and posterior. — Low mostly herbaceous fleshy leafless saline plants, with oppositely branched jointed stems; spikes cylindrical. The spongy calyx is composed mainly of spiral vessels.

1. S. MUCRONATA, Bigel. Annual, herbaceous, stout, erect, 2–12 inches high, shortly branched; spikes 1–2½ inches long, 1½–2 lines broad, very closely jointed, rather obtuse; scales acutely pointed, becoming divaricate and conspicuous; middle flower a half higher than the lateral ones or less, occupying nearly the whole length of the joint; fruit pubescent; seed ½–⅔ of a line long. — On the seacoast from Nova Scotia to Virginia. The specimen of Gronovius in herb. Clayton on which Linnæus founded his *S. Virginica* has been identified by Dr. Gray as *S. herbacea*.

Salicornia mucronata. Bigelow, Fl. Bost., 2 ed., 2; not Lagasca. Torrey, Fl. N.Y. 2. 140. Matthew, Canad. Nat. 12. 159. Gray, Manual, 1 ed., 377.

Salicornia Virginica. Moquin, DC. Prodr. 13². 145, in part; not Linn. Gray, Manual, 410.

Salicornia Bigelovii. Torrey Bot. Mex. Bound. 184.

Var. SUFFRUTESCENS. Stout, woody at base, 1–2 feet high, much branched, spikes rather acute, and seed ¾–1 line long; otherwise like the northern herbaceous plant, of which it is probably but a well-developed form. — Key West (Blodgett); Santiago, at the mouth of the Rio Grande (Schott).

Salicornia mucronata. Torrey, Bot. Mex. Bound. 184; also Lagasca ??

2. S. HERBACEA, Linn. Annual, herbaceous, erect, rather slender; ½–1½ feet high, usually diffusely branched; spikes 1–3 inches long, becoming 1–1½ lines wide, narrower and longer jointed than in the last; scales narrow, truncate or shortly acute; middle flower twice higher than the lateral ones, slightly shorter than the joint; fruit pubescent; seed ⅔ to nearly a line long. — Seacoast and saline localities from Nova Scotia to Georgia, and inward to the Saskatchewan and Salt Lake Valley; "Oregon." Differing from the Old World form only in the usually somewhat longer-jointed and less densely flowered spikes. The radicle is occasionally found twisted upon itself and erect.

Salicornia herbacea, Linn. Michaux, Flora, 1. 1. Pursh, 2. Elliott, 1. 3. Hook. Fl. Bor.-Am. 2. 125. Torrey, Nicollet's Rep. 159; Emory's Rep. 411; Flora N. Y. 2. 140. Moquin, DC. Prodr. 13². 144. Engelm. Pl. Upp. Miss. 206. Durand, Fl. Utah, 174. Chapman, 378. Bourgeau, Palliser's Rep. 260. Matthew, Canad. Nat. 12. 159. Gray, Manual, 410. Watson, King's Rep. 5. 298. Coulter, Hayden's Rep., 1872, 779. Porter, Fl. Col. 118.

Salicornia Virginica, Linn. Pursh, Flora, 2. Nuttall, Genera, 1. 145. Porter, Hayden's Rep., 1870, 481.

Salicornia herbacea, var. *prostrata.* Bourgeau, Palliser's Rep. 260; not Moquin.

Collectors: — 677 Fremont; Abert; Bourgeau; 994 Watson; Hayden; Scoville; Burgess; Gray; Allen.

3. S. AMBIGUA, Michx. Stems decumbent and rooting at the joints or ascending, from a rather woody perennial rootstock, ½–1 foot long, simple or simply branched, "greenish turning lead-color;" spikes ½–1 inch long, slender, short-jointed, the scales short, acutish or acute; flowers nearly equal in height and equalling the joint; seed pubescent, ⅓ of a line long. — Seacoast from Massachusetts to Florida and Texas; Oregon and California. *S. fruticosa* of the Old World differs in being erect, stouter and more branched, the seed larger and smooth.

Salicornia ambigua. Michx., Flora, 1. 2. Elliott, Sketch, 1. 4. Spreng. Syst. 1. 18. Torrey, Flora N.Y. 2. 141; Bot. Wilkes's Exp. 438. Chapman, Flora, 378.

Salicornia radicans. Hook. Fl. Bor.-Am. 2. 125.

Arthrocnemum (?) *ambiguum.* Moquin, Enum. Chenop. 112; DC. Prodr. 13^2. 151.

Arthrocnemum fruticosum, var. *Californicum.* Moquin, DC. Prodr. 13^2. 151. Newberry, Pac. R. R. Rep. 6. 88.

Salicornia fruticosa. Torrey, Pac. R. R. Rep. 5. 364.

Salicornia herbacea. Cooper, Pac. R. R. Rep. 12. 68. Bolander, Catalogue, 25.

Collectors:—Blodgett; Scouler; Chamisso; Wilkes; 264 Drummond; Lindheimer; Wright; Lyall; Cooper; 2491 Brewer; Allen.

17. SPIROSTACHYS, Sternberg.

Flowers perfect, arranged spirally by threes in a crowded spike, in the axils of fleshy subsessile bracts. Calyx of 4 (rarely 5) concave carinate imbricated sepals, more or less united. Stamens 1–2, with slender filaments at length exserted. Ovary oblong, axial: styles 2, rarely 3, usually distinct. Fruit vertical, the membranous pericarp free from the seed. Seed oblong, with a double membranous testa: albumen rather copious, nearly three-fourths surrounded by the embryo; radicle inferior and basal, much longer than the cotyledons. — Alkaline or saline jointed shrubs with alternate leafless branches, the branchlets fleshy, green, with short scalelike leaves.

Much confusion has existed in regard to the genera of this tribe (*Salicorneæ*) since the time of Moquin, whose errors have been pointed out by Fenzl, Bunge, and more recently and fully by Sternberg. The present genus was founded upon the South American species *S. Ritteriana*, the only other species known. *Arthrocnemum* and *Halostachys*, to which they have been referred, are genera with opposite branches, &c., like *Salicornia*. An Asian genus, *Halopeplis*, is distinguished mainly by its superior radicle.

1. S. OCCIDENTALIS. Erect, diffusely branched, 2–5 feet high. Leaves very short, broadly triangular and amplexicaul, acute, often nearly

obsolete; spikes numerous, sessile or nearly so, cylindrical, 3–10 lines long; bracts rhomboidal; flowers crowded, slightly exserted; calyx becoming spongy and enclosing the fruit; seed less than a fourth of a line long. — Throughout the Great Basin from Northern Nevada and Utah to Arizona and Western Texas; California, in San Joaquin Valley, near the Sacramento (Brewer).

Arthrocnemum fruticosum Torrey, Stansbury's Rep. 394; not Moq. Durand, Fl. Utah, 174.

Arthrocnemum macrostachyum. Torrey, Bot. Mex. Bound. 184; Ives's Rep. 25; not Bunge.

Halostachys occidentalis. Watson, King's Rep. 5. 293. Coulter, Hayden's Rep., 1872, 779.

Collectors: — 760 Fremont; Emory; 577, 1745 Wright; Stansbury; 100 Thurber; 189 Bigelow; Schott; Newberry; H. Engelmann; 467 Torrey; Palmer; 1191 Brewer; 994 Watson; Wheeler; Burgess.

VII.

ON THE PERIODIC ERRORS OF THE RIGHT ASCENSIONS OBSERVED BETWEEN 1858 AND 1871.

BY WILLIAM A. ROGERS.

Read, April 14, 1874.

PART I.

IT is the purpose of this investigation to determine for the Right Ascensions observed between 1858 and 1871, the periodic errors of single period, as expressed by an equation of the form:—

$$m \sin a + n \cos a \quad = r.$$

The periodic errors of double period, as expressed by an equation of the form:—

$$m' \sin 2\,a + n' \cos 2\,a = r'.$$

And the periodic errors depending on the Declination, as expressed by an equation of the form:—

$$a \sin \delta + b \cos \delta \quad = r''.$$

The complete solution of the problem requires:—

(*a*) That the assumed Right Ascensions with which any system of observations is compared shall be free both from periodic and from accidental errors.

(*b*) That the system of observations whose periodic errors are to be determined shall be free from accidental errors.

From the nature of the case, neither of these conditions can be exactly fulfilled; but an approximate solution may be had by either of the following methods:—

I. A standard catalogue may be selected, in which especial care has been taken to eliminate periodic errors of single period, by making the clock errors employed in the reductions, depend upon observations

separated by an interval of 12 hours. By employing a large number of stars, accidental errors may be nearly eliminated from the mean of any group. With this standard catalogue any other catalogue may be compared, and from the mean of the residuals about each hour of Right Ascension there may be formed 24 equations of the form: —

$$m \sin 1^h + n \cos 1^h = r,$$
$$m \sin 2^h + n \cos 2^h = r_1, \text{ \&c.},$$

from which m and n can be obtained by the process of least-squares. Either the Pulkowa catalogue for 1845, the Aboë catalogue for 1828, or the Dorpat catalogue for 1830, might be selected for this purpose with great advantage, were it not for the occasional uncertainty in the value of the proper motions with which the Right Ascensions are brought forward to the present time. But it will be seen from this investigation, that no series of observations made since 1858 is wholly free from the errors in question.

In the earlier investigations on this subject, especially in the one given by Professor Safford (Monthly Notices of the Royal Astronomical Society, Vol. XXI., No. 9), who seems to have been the first to suggest the present form of discussion, the standard or Greenwich 12 Year Catalogue, is assumed to be free from periodic errors. A similar assumption with respect to the Washington Observations seems also to have been partially made by Professor Newcomb, in deriving the periodic equation for Dr. Gould's catalogue of fundamental stars from the Washington Observations from 1862 to 1867. (Washington Observations for 1867.) While the error arising from this source is inconsiderable in the latter case, it has nevertheless a sensible magnitude.

II. Instead of depending upon a large number of stars to secure freedom from accidental errors, we may employ only the Maskelyne fundamental stars of the first and second magnitude, relying for our purpose, upon their more accurately determined places. If the assumed Right Ascensions of these stars have been determined by a process from which differential observations have been excluded, and in which great care has been taken to employ only data from which periodic errors have been eliminated by the method of observation, the whole system of Right Ascensions may be regarded as homogeneous. Even if this condition is not exactly fulfilled, if the periodic coefficients for different catalogues have opposite signs, the resulting system may safely be assumed to be nearly homogeneous, and nearly free from periodic errors of all kinds.

If, from the standard catalogue thus formed, accidental errors can be excluded, comparing with any other catalogue, we shall have directly for each star periodic equations of the form, —

$$\begin{aligned} m \sin a \quad &+ n \cos a \quad = r, \\ m' \sin 2a &+ n' \cos 2a = r', \\ a \sin \delta \quad &+ b \cos \delta \quad = r''; \end{aligned}$$

from which, the periodic coefficients can be successively found by least-squares; and, with these coefficients thus obtained, a system of corrections may be computed for each hour of Right Ascension.

In the absence of any system of observations since 1858, made with especial reference to freedom from periodic errors, this method will be employed in this investigation. The standard catalogue selected, is given by the following title: —

"On the Right Ascensions of the Equatorial Fundamental Stars, and the Corrections necessary to reduce the Right Ascensions of Different Catalogues to a Mean Homogeneous System. By Simon Newcomb, Professor of Mathematics, United States Navy."

This catalogue of 32 fundamental stars proves to be far more accurate than any hitherto constructed. Indeed, it seems almost superfluous to attempt any corrections for accidental errors. I shall, however, venture a thorough comparison with only modern observations, on the supposition that they are somewhat more accurately made than earlier ones, especially those made since the introduction of the chronograph.

Since the assumed system of Right Ascensions is supposed to be entirely homogeneous, the corrections obtained will be independent of the time of observation; and, when once obtained, may be applied to the whole system. I conceive it to be possible, in this way (assuming, of course, that the annual variations are correctly known), to correct the accidental errors of any part of the system, by observations made at the point of time and under the conditions most favorable to accuracy.

A preliminary and tentative discussion, by the method above indicated, gave the following periodic equations, viz.: —

	s. s. s.
GREENWICH. — Observations from 1860 to 1870,	$r = -.010 \sin a + .007 \cos a.$
EDINBURGH. — Observations from 1860 to 1869,	$r = -.009 \sin a + .006 \cos a.$
OXFORD. — Observations from 1860 to 1870,	$r = -.012 \sin a + .019 \cos a.$
WASHINGTON. — Observations from 1860 to 1870,	$r = -.009 \sin a + .007 \cos a.$
HARVARD COLLEGE. — Observations in 1871,	$r = -.010 \sin a + .003 \cos a.$

After reducing the equinox of the different catalogues to that of the standard catalogue, and subtracting from the residuals given by direct

comparison with observation, the values of r derived from the periodic equations of single period, the following corrections to Newcomb's catalogue were obtained, viz.: —

CORR. $+.00^s$	CORR. $+.01^s$	CORR. $-.01^s$	CORR. $+.02^s$	CORR. $-.02^s$
α Andromedæ,	β Orionis,	γ Pegasi,	α Canis Majoris,	α Aurigæ.
α Arietis,	β Tauri,	α Scorpii,	α Piscis Aust.	
α Ceti,	α Orionis,	α Aquilæ,		
α Tauri,	α Canis Minoris,	α Cygni.		
β Geminorum,	α Bootis,			
α Hydræ,	α^2 Libræ,			
α Leonis,	α Serpentis,			
β Leonis,	α Ophiuchi,			
α Virginis,	γ Aquilæ,			
α Coronæ,	β Aquilæ,			
α Herculis,	α^2 Capricorni,			
α Lyræ,	α Aquarii.			
α Pegasi.				

The slight preponderance of positive corrections is due, partly to the fact that only the nearest hundredth of a second was taken, and partly to the fact that no account was taken of corrections depending on the Declination. It will be found that there is a general tendency to positive corrections, when the corrections for errors of single period only, are applied. The introduction of corrections for errors of double period has a slight tendency to restore the equilibrium. It is only when the corrections depending on the Declination are applied that the equinox is restored to its original assumed position.

In this discussion of late observations, the following data will be employed: —

(1) Greenwich. — The Greenwich Observations from 1858 to 1870, inclusive.

(2) Washington, I. — The Washington Observations from 1862 to 1870. The Right Ascensions given are found by applying the corrections to the American Ephemeris, given in the annual volumes. The epoch for the years 1862–3–4 is 1860.0. For the remaining years it is 1870.0.

(3) Washington, II. — The Washington Observations from 1858 to 1861. These observations, mostly made by Professor Yarnall, are purely differential, and depend on the positions given in the Nautical Almanac for 1860. As they show an excellent agreement *inter se*, their discussion will show how far the periodic errors of the standard catalogue are transferred to the observed.

(4) Paris. — The Paris Observations from 1858 to 1866.

(5) Melbourne. — The Melbourne Observations from 1858 to 1868. The places for 1860 depend on the observations of 1858–59–60.

(6) Brussels. — The Brussels Observations from 1858 to 1866.

(7) OXFORD. — The Oxford Observations from 1858 to 1870.

(8) EDINBURGH. — The Edinburgh Observations from 1860 to 1869.

(9) HARVARD COLLEGE. — The Harvard College Observations for 1871. The places are taken from Ast. Nach., Nos. 1909 and 1947, except those for α Bootis, α Scorpii, α Ophiuchi, and α Lyræ, which depend on the observations there given, and upon additional observations in 1872. The corrections are as follows: —

α Bootis	$= +.02^s$
α Scorpii	$= +.06$
α Ophiuchi	$= -.01$
α Lyræ	$= +.08$

On the following pages are arranged: —

First, The assumed Right Ascension of each star; and, under the various authorities, the observed places in hundredths of seconds.

Second, The residuals formed by subtracting the observed from the assumed Right Ascensions. Instead of attempting to apply weights proportional to the number of observations, discordant results which depend on 3 observations or less are included in brackets, to indicate their rejection. Beyond this, all observations are assumed to have equal weight.

TABULAR AND OBSERVED RIGHT ASCENSIONS.

α Andromedæ.		Paris.	Green-wich.	Mel-bourne.	Brussels.	Oxford.	Edin-burgh.	Washing-ton, I.	Washing-ton, II.	Harvard College.
	h. m. s.	s.	s.	s.	s.	s.	s.	s.	s.	s.
1858	0 1 3.28	.24	.28		.17				.36	
1859	1 6.37	.29	.37		.28				.42	
1860	1 9.45	.37	.47	.40	.31	.38	.40		.34	
1861	1 12.54	.49	.53		.44	.46	.47		.32	
1862	1 15.63	.58	.57		.54	.60	.59	.42		
1863	1 18.71	.68	.67	.61	.68	.54	.70	.42		
1864	1 21.80	.74	.80	.71	.78	.71	.78	.45		
1865	1 24.89	.85	.84	.84	.86	.82	.88	.27		
1866	1 27.97	.91	.95	.90	.96	.81	.94	.30		
1867	1 31.06		.05	.95		.01	.02	.30		
1868	1 34.15		.14	.10		.24	.11	.29		
1869	1 37.24		.19			.18	.19	.29		
1870	1 40.32		.28			.28		.32		
1871	1 43.41									.36
γ Pegasi.										
1858	0 5 55.65	.60	.65		.60				.72	
1859	5 58.73	.70	.72		.67				.77	
1860	6 1.81	.75	.77	.75	.78	.77	.76		.76	
1861	6 4.89	.88	.87		.82	.90	.90		.74	
1862	6 7.97	.89	.90			.85	.94	.78		
1863	6 11.05	.00	.97	.95	.02	.88	.02	.77		
1864	6 14.13	.07	.10	.08	.07	.00	.09	.78		
1865	6 17.21	.16	.17	.14	.10	.14	.21	.59		
1866	6 20.29	.28	.27	.22		.25	.27	.64		
1867	6 23.38		.34	.32		.32	.38	.61		
1868	6 26.46		.42	.40		.38	.46	.64		
1869	6 29.54		.53			.50	.52	.60		
1870	6 32.62		.55			.68		.69		
1871	6 35.70									.69
α Arietis.										
1858	1 59 10.57	.50	.57		.49				.25	
1859	59 13.94	.89	.92		.84				.24	
1860	59 17.30	.27	.28	.25	.25	.25	.29		.24	
1861	59 20.67	.68	.62		.57	.64	.60		.24	
1862	59 24.04	.01	.02		.01	.96	.01	.29		
1863	59 27.40	.34	.42	.28	.30	.37	.38	.27		
1864	59 30.77	.70	.73	.72	.73	.68	.77	.29		
1865	59 34.13	.09	.09	.10	.05	.12	.10	.96		
1866	59 37.50	.47	.47	.42	.40	.46	.46	.95		
1867	59 40.86		.82	.76		.88	.81	.95		
1868	59 44.23		.18	.17		.25	.22	.95		
1869	59 47.60		.53			.69	.54	.95		
1870	59 50.97		.92			.99		.97		
1871	59 54.33									.28

TABULAR AND OBSERVED RIGHT ASCENSIONS (*continued*).

α Ceti.		Paris.	Greenwich.	Melbourne.	Brussels.	Oxford.	Edinburgh.	Washington, I.	Washington, II.	Harvard College.
	h. m. s.	s.	s.	s.	s.	s.	s.	s.	s.	s.
1858	2 54 51.62	.58	.63		.48				.81	
1859	54 54.74	.72	.73		.68				.82	
1860	54 57.87	.82	.81	.81	.90	.89	.87		.81	
1861	55 1.00	.97	.01		.95	.05	.92		.79	
1862	55 4.12	.04	.08		.00	.16	.05	.87		
1863	55 7.25	.19	.22	.20	.22	.19	.21	.89		
1864	55 10.38	.38	.35	.35	.37	.30	.29	.36		
1865	55 13.51	.49	.49	.48	.48	.50	.46	.16		
1866	55 16.64	.62	.62	.60	.63	.60	.55	.16		
1867	55 19.77		.78	.78		.75	.70	.15		
1868	55 22.89		.88	.85		.88	.82	.18		
1869	55 26.02		.96			.98	.95	.18		
1870	55 29.15		.10			.06		.19		
1871	55 32.28									25

α Tauri.		Paris.	Greenwich.	Melbourne.	Brussels.	Oxford.	Edinburgh.	Washington, I.	Washington, II.	Harvard College.
1858	4 27 46.57	.57	.54		.54				.40	
1859	27 50.00	.99	.00		.96				.42	
1860	27 53.44	.43	.42	.40	.39	.43	.42		.42	
1861	27 56.87	.84	.88		.82	.82	.84		.40	
1862	28 0.30	.28	.27		.30	.20	.28	.45		
1863	28 3.74	.72	.73	.71	.70	.72	.73	.46		
1864	28 7.17	.17	.16	.18		.22	.18	.44		
1865	28 10.61	.58	.61	.60	.58	.64	.62	.78		
1866	28 14.04	.00	.02	.99	.03	.06	.00	.76		
1867	28 17.48		.48	.48		.40	.48	.77		
1868	28 20.91		.90	.86		.97	.90	.76		
1869	28 24.35		.31			.32	.32	.79		
1870	28 27.79		.76			.78		.78		
1871	28 31.22									.19

α Aurigæ.		Paris.	Greenwich.	Melbourne.	Brussels.	Oxford.	Edinburgh.	Washington, I.	Washington, II.	Harvard College.
1858	5 6 12.26	.27	.25		.20				.07	
1859	6 16.68	.70	.72		.60				.09	
1860	6 21.10	.11	.14	.12	.96	.06			.06	
1861	6 25.52	.50	.54			.44			.03	
1862	6 29.94	.87	.95		.93	.65		.02		
1863	6 34.36	.39	.32		.31			.12		
1864	6 38.78	.85	.82	.74	.75	.99				
1865	6 43.20	.18	.14	.22		.71		.15		
1866	6 47.62	.49	.60	.76	.53			.29		
1867	6 52.04		.07	.98				.21		
1868	6 56.46		.42	.51				.36		
1869	7 0.88		.84			.91		.28		
1870	7 5.31		.20			.25		.39		
1871	7 9.74									.67

TABULAR AND OBSERVED RIGHT ASCENSIONS (*continued*).

β Orionis.		Paris.	Greenwich.	Melbourne.	Brussels.	Oxford.	Edinburgh.	Washington, I.	Washington, II.	Harvard College.
	h. m. s.	s.	s.	s.	s.	s.	s.	s.	s.	s.
1858	5 7 42.91	.92	.89						.72	
1859	7 45.79	.80	.78		.79				.69	
1860	7 48.67	.68	.64	.64	.71	.62			.70	
1861	7 51.55	.55	.51			.37	.53		.70	
1862	7 54.43	.46	.39		.43	.47	.39	.65		
1863	7 57.31	.34	.26	.27	.23	.26	.28	.67		
1864	8 0.19	.22	.18	.17	.14	.23	.05	.67		
1865	8 3.07	.07	.03	.05	.10	.09	.96	.46		
1866	8 5.95	.96	.92	.93		.93	.94	.46		
1867	8 8.83		.84	.80		.79	.71	.45		
1868	8 11.71		.67	.67		.83	.68	.45		
1869	8 14.59		.53			.54	.54	.51		
1870	8 17.47		.39			.42		.43		
1871	8 20.35									.35
β Tauri.										
1858	5 17 19.09	.04	.07		.12				.54	
1859	17 22.87	.84	.85		.86				.59	
1860	17 26.66	.65	.72	.65	.66	.69	.75		.60	
1861	17 30.45	.41	.42		.36	.53	.52		.54	
1862	17 34.24	.20	.18		.22	.21	.24	.66		
1863	17 38.02	.96	.02		.01	.98	.03	.68		
1864	17 41.81	.79	.81	.75	.77	.80	.82	.68		
1865	17 45.60	.58	.61	.57	.78	.54	.64	.50		
1866	17 49.38	.37	.36	.34	.45	.37	.42	.51		
1867	17 53.17		.11	.17		.13	.18	.52		
1868	17 56.96		.96	.94			.94	.52		
1869	18 0.75		.70			.68	.76	.49		
1870	18 4.54		.51			.48		.54		
1871	18 8.33									.29
α Orionis.										
1858	5 47 29.10	.10	.06		.05					
1859	47 32.35	.30	.35		.31				.56	
1860	47 35.60	.56	.60	.57	.52	.58	.50		.55	
1861	47 38.84	.80	.76		.85	.78	.78		.61	
1862	47 42.09	.06	.05		.09	.04	.08	.60		
1863	47 45.33	.34	.30	.31	.34	.31	.30	.60		
1864	47 48.58	.58	.57	.57	.49	.57	.56	.60		
1865	47 51.83	.80	.87	.80	.81	.81	.76	.07		
1866	47 55.07	.06	.03	.07	.05	.10	.08	.04		
1867	47 58.32		.31	.34		.42	.28	.03		
1868	48 1.57		.55	.56		.47	.53	.05		
1869	48 4.81		.67			.93	.82	.07		
1870	48 8.06		.00			.01		.08		
1871	48 11.31									.31

TABULAR AND OBSERVED RIGHT ASCENSIONS (*continued*).

α Canis Majoris.		Paris.	Greenwich.	Melbourne.	Brussels.	Oxford.	Edinburgh.	Washington, I.	Washington, II.	Harvard College.
	h. m. s.	s.	s.	s.	s.	s.	s.	s.	s.	s.
1858	6 38 53.37	.86	.29		.89					
1859	38 56.00	.01	.99		.99				.70	
1860	38 58.64	.61	.61	.61	.61	.68			.68	
1861	39 1.28	.29	.24		.23	.15			.75	
1862	39 3.92	.90	.88			.89		.64		
1863	39 6.56	.55		.55	.60	.55		.64		
1864	39 9.19	.18	.14	.18	.20	.98		.65		
1865	39 11.83	.85	.80	.78	.84			.10		
1866	39 14.48	.48	.42	.44		.48		.06		
1867	39 17.12		.10	.06		.17		.06		
1868	39 19.76		.71	.72				.93		
1869	39 22.41		.88			.84		.90		
1870	39 25.05		.98			.02		.12		
1871	39 27.70									
α Canis Minoris.										
1858	7 31 52.08	.08	.08		.07				.88	
1859	31 55.22	.20	.17		.21				.37	
1860	31 58.36	.81	.38	.82	.36	.35	.34		.38	
1861	32 1.50	.47	.51		.51	.44	.44		.35	
1862	32 4.63	.59	.60		.62	.59	.60	.36		
1863	32 7.77	.77	.76	.75	.84	.77	.70	.85		
1864	32 10.90	.89	.87	.92	.07	.93	.87	.84		
1865	32 14.03	.05	.02	.03	.08	.00	.93	.80		
1866	32 17.17	.19	.15	.14	.18	.15	.11	.75		
1867	32 20.30		.28	.30		.26	.26	.75		
1868	32 23.43		.42	.42		.40	.48	.71		
1869	32 26.57		.58			.59	.54	.74		
1870	32 29.71		.67			.67		.68		
1871	32 32.84									.84
β Geminorum.										
1858	7 36 37.30	.26	.29		.25				.62	
1859	36 40.98	.95	.97		.95				.66	
1860	36 44.66	.64	.68	.67	.61	.64	.60		.63	
1861	36 48.35	.81	.32		.31	.98	.36		.68	
1862	36 52.03	.09	.02		.94	.04	.04	.68		
1863	36 55.71	.69	.71		.78	.67	.73	.67		
1864	36 59.40	.88	.40	.85		.25	.41	.69		
1865	37 3.08	.08	.10	.04	.12		.06	.51		
1866	37 6.76	.75	.72	.77	.80	.69	.80	.45		
1867	37 10.44		.40	.45		.46	.44	.48		
1868	37 14.12		.10	.11		.09	.12	.47		
1869	37 17.80		.77			.83	.80	.50		
1870	37 21.49		.48			.49		.48		
1871	37 25.17									.16

TABULAR AND OBSERVED RIGHT ASCENSIONS (*continued*)

α Hydræ.		Paris.	Green-wich.	Mel-bourne.	Brussels.	Oxford.	Edin-burgh.	Washing-ton, I.	Washing-ton, II.	Harvard College.
	h. m. s.	*s.*	*s.*	*s.*	*s.*	*s.*	*s.*	*s.*	*s.*	*s.*
1858	9 20 36.55	.54	.55		.60					
1859	20 39.50	.58	.51		.47				.46	
1860	20 42.45	.45	.39	.43	.44	.43	.32		.42	
1861	20 45.40	.42	.35		.39	.41			.46	
1862	20 48.35	.33	.29		.31	.35	.28	.45		
1863	20 51.29	.31	.26	.28	.33	.27		.48		
1864	20 54.24	.23	.26	.22	.21		.15	.44		
1865	20 57.19	.20	.20	.20	.18	.17	.10	.97		
1866	21 0.14	.16	.15	.17	.16	.21		.92		
1867	21 3.09		.08	.07		.08	.02	.93		
1868	21 6.04		.05	.01		.02		.96		
1869	21 8.99		.99			.98	.94	.96		
1870	21 11.94		.92			.87		.97		
1871	21 14.89									.90
α Leonis.										
1858	10 0 48.36	.35	.38		.32				.82	
1859	0 51.56	.52	.57		.56				.75	
1860	0 54.77	.77	.74	.77	.74	.71	.79		.76	
1861	0 57.97	.96	.98		.96	.92	.94		.78	
1862	1 1.17	.22	.17		.16	.06	.16	.78		
1863	1 4.38	.36	.31		.36	.46	.38	.80		
1864	1 7.58	.59	.59	.59	.55	.61	.55	.84		
1865	1 10.78	.76	.71	.76	.71	.75	.79	.83		
1866	1 13.99	.97	.99	.96		.97	.98	.77		
1867	1 17.19		.17	.20		.16	.18	.77		
1868	1 20.39		.38	.38		.35	.40	.78		
1869	1 23.59		.55			.61	.54	.81		
1870	1 26.80		.76			.78		.79		
1871	1 30.00									.98
β Leonis.										
1858	11 41 48.85	.83	.86		.82					
1859	41 51.91	.86	.91		.88				.93	
1860	41 54.98	.97	.99	.96	.97	.98	.96		.92	
1861	41 58.05	.99	.05		.02	.08	.07		.89	
1862	42 1.11	.11	.06		.06	.05	.12	.00		
1863	42 4.18	.12	.16		.16	.18	.17	.98		
1864	42 7.24	.22	.24	.20	.22	.21	.24	.02		
1865	42 10.31	.32	.29	.27	.27	.30	.32	.64		
1866	42 13.37	.37	.38	.29	.31	.37	.37	.68		
1867	42 16.44		.45	.39		.45	.45	.68		
1868	42 19.51		.48	.46		.41	.49	.64		
1869	42 22.57		.57			.66	.55	.67		
1870	42 25.64		.62			.59		.68		
1871	42 28.70									.67

TABULAR AND OBSERVED RIGHT ASCENSIONS (*continued*).

α Virginis.		Paris.	Greenwich.	Melbourne.	Brussels.	Oxford.	Edinburgh.	Washington, I.	Washington, II.	Harvard College.
	h. m. s.	s.	s.	s.	s.	s.	s.	s.	s.	s.
1858	13 17 43.00	.99	.98		.97				.82	
1859	17 46.15	.11	.10		.08				.24	
1860	17 49.30	.27	.26	.26	.22	.29			.26	
1861	17 52.45	.45	.43		.40	.48			.29	
1862	17 55.60	.59	.59		.56	.74		.81		
1863	17 58.76	.76	.78	.73	.66	.76	.60	.81		
1864	18 1.91	.92	.87	.87	.84	.90	.82	.82		
1865	18 5.06	.07	.04	.02		.08		.84		
1866	18 8.21	.12	.18	.20	.20	.25	.11	.81		
1867	18 11.36		.33	.34			.28	.82		
1868	18 14.51		.46	.46			.48	.81		
1869	18 17.66		.64			.59		.81		
1870	18 20.81		.71			.85		.79		.94
1871	18 23.97									
α Bootis.										
1858	14 9 11.16	.18	.14		.10				.56	
1859	9 13.89	.86	.88		.82				.60	
1860	9 16.63	.59	.61	.57	.57	.55	.63		.55	
1861	9 19.36	.30	.33		.32	.35	.32		.52	
1862	9 22.09	.98	.06		.07	.04	.04	.62		
1863	9 24.83	.80	.79	.78	.72	.85	.82	.61		
1864	9 27.56	.53	.56	.46		.65	.54	.64		
1865	9 30.30	.23	.26	.20	.26	.33	.33	.95		
1866	9 33.03	.97	.99	.00	.99	.99	.00	.94		
1867	9 35.77		.74	.72		.76	.75	.95		
1868	9 38.50		.45	.43		.53	.50	.94		
1869	9 41.24		.19			.23	.22	.98		
1870	9 43.97		.89			.92		.95		
1871	9 46.70									.68
α^2 Libræ.										
1858	14 43 1.74	.74	.69		.68					
1859	43 5.05	.06	.98		.04				.28	
1860	43 8.35	.31	.29	.28	.26	.32			.29	
1861	43 11.66	.64	.62		.59	.61			.29	
1862	43 14.96	.94	.93		.88	.94		.82		
1863	43 18.27	.25	.23	.25	.15	.28		.82		
1864	43 21.57	.55	.53	.53	.53	.51		.80		
1865	43 24.88	.84	.86	.86	.78	.90		.89		
1866	43 28.19	.18	.18	.16	.19	.17		.41		
1867	43 31.49		.50	.45		.48		.41		
1868	43 34.80		.74	.74		.82		.40		
1869	43 38.10		.10			.11		.44		
1870	43 41.41		.40			.41		.40		
1871	43 44.72									.74

TABULAR AND OBSERVED RIGHT ASCENSIONS (*continued*).

α Coronæ.		Paris.	Green-wich.	Mel-bourne.	Brussels.	Oxford.	Edin-burgh.	Washing-ton, I.	Washing-ton, II.	Harvard College.
	h. *m.* *s.*	*s.*	*s.*	*s.*	*s.*	*s.*	*s.*	*s.*	*s.*	*s.*
1858	15 28 40.61	.58	.60		.55				.60	
1859	28 43.15	.09	.18		.05				.58	
1860	28 45.69	.62	.69	.63	.64	.67	.70		.57	
1861	28 48.23	.14	.21		.20	.21	.20		.57	
1862	28 50.76	.68	.76		.72	.72	.77	.67		
1863	28 53.30	.24	.28	.24	.18	.31	.31	.65		
1864	28 55.84	.76	.81	.71	.78	.83	.85	.70		
1865	28 58.38	.38	.35	.31	.38	.36	.41	.05		
1866	29 0.92	.88	.89	.83	.87	.91	.93	.03		
1867	29 3.46		.44			.38	.46	.06		
1868	29 6.00		.96	.92		.10	.99	.08		
1869	29 8.53		.50			.52	.54	.07		
1870	29 11.07		.01			.07		.06		
1871	29 13.61									.57
α Serpentis.										
1858	15 37 16.57	.52	.54		.53					
1859	37 19.52	.48	.49		.42				.39	
1860	37 22.47	.41	.44	.41	.42	.43	.44		.39	
1861	37 25.42	.36	.40		.38	.37			.38	
1862	37 28.37	.35	.31		.29	.39	.34	.44		
1863	37 31.32	.28	.26	.24	.28	.31	.28	.44		
1864	37 34.27	.25	.28	.21	.22	.23	.19	.51		
1865	37 37.22	.17	.20	.15	.10	.21	.17	.92		
1866	37 40.17	.15	.12	.08		.13	.13	.96		
1867	37 43.12		.12	.06		.06	.07	.99		
1868	37 46.08		.04	.99		.99	.02	.97		
1869	37 49.03		.95			.03	.97	.99		
1870	37 51.98		.91			.98		.96		
1871	37 54.93									.91
α Scorpii.										
1858	16 20 42.38	.38	.35		.32	·			.74	
1859	20 46.05	.07	.98		.95				.67	
1860	20 49.72	.75	.63	.66	.62	.70			.67	
1861	20 53.38	.40	.34		.28	.37			.71	
1862	20 57.05	.08	.00		.97	.98		.71		
1863	21 0.71	.71	.73	.68	.65	.65		.72		
1864	21 4.38	.39		.32	.29	.31		.72		
1865	21 8.05	.06	.01	.97	.01	.07		.86		
1866	21 11.71	.68	.72	.68	.70	.72		.40		
1867	21 15.38		.38	.30		.39		.48		
1868	21 19.05		.01	.97				.87		
1869	21 22.71		.68			.74		.41		
1870	21 26.38		.38			.32		.82		
1871	21 30.05									.04

TABULAR AND OBSERVED RIGHT ASCENSIONS (*continued*).

a Herculis.		Paris.	Green-wich.	Mel-bourne.	Brussels.	Oxford.	Edin-burgh.	Washing-ton, I.	Washing-ton, II.	Harvard College.
	h. m. s.	*s.*	*s.*	*s.*	*s.*	*s.*	*s.*	*s.*	*s.*	*s.*
1858	17 8 10.45	.40	.40						.84	
1859	8 13.18	.14	.25		.04				.81	
1860	8 15.91	.85	.89	.85	.85	.79	.84		.82	
1861	8 18.65	.61	.58		.48	.47	.63		.82	
1862	8 21.38	.31	.42		.28	.29	.40	.90		
1863	8 24.11	.04	.02	.06	.93	.05	.06	.90		
1864	8 26.84	.78	.86	.76	.62	.81	.85	.88		
1865	8 29.58	.54	.56	.47	.48	.55	.54	.22		
1866	8 32.31	.27	.30	.22	.18	.24	.28	.23		
1867	8 35.04		.03	.93		.96	.05	.23		
1868	8 37.78		.74	.70		.58	.76	.24		
1869	8 40.51		.49			.51	.47	.25		
1870	8 43.24		.22			.18		.20		
1871	8 45.97									.94
a Ophiuchi.										
1858	17 28 20.67	.61	.64		.55				.18	
1859	28 23.46	.41	.43		.37				.14	
1860	28 26.24	.20	.22	.15	.13	.13	.23		.13	
1861	28 29.02	.97	.97			.92	.94		.14	
1862	28 31.80	.71	.77		.71	.76	.77	.21		
1863	28 34.58	.53	.59	.51	.49	.54	.54	.21		
1864	28 37.37	.33	.35	.28	.23	.35	.31	.18		
1865	28 40.15	.08	.13	.05	.09	.14	.11	.02		
1866	28 42.93	.86	.90	.84		.87	.84	.02		
1867	28 45.71		.69	.60		.69	.65	.06		
1868	28 48.49		.45	.39		.48	.47	.04		
1869	28 51.28		.24			.22	.18	.02		
1870	28 54.06		.02			.07		.03		
1871	28 56.84									.82
a Lyræ.										
1858	18 32 7.87	.80	.90							
1859	32 9.90	.82	.84		.87				.79	
1860	32 11.93	.85	.86	.85	.84	.89	.91		.78	
1861	32 13.96	.90	.93		.93	.83	.87		.76	
1862	32 15.99	.87	.95		.88	.92		.90		
1863	32 18.02	.94	.00	.88	.98	.91	.00	.89		
1864	32 20.06	.96	.03	.88	.91	.11	.02	.91		
1865	32 22.09	.99	.05	.92	.99	.03	.02	.20		
1866	32 24.12	.00	.09	.02	.02	.10	.06	.22		
1867	32 26.15		.12	.05		.06	.11	.23		
1868	32 28.18		.14	.09		.22	.14	.20		
1869	32 30.21		.17			.14	.18	.23		
1870	32 32.24		.16			.16		.21		
1871	32 34.27									.24

TABULAR AND OBSERVED RIGHT ASCENSIONS (*continued*).

γ Aquilæ.		Paris.	Green-wich.	Mel-bourne.	Brussels.	Oxford.	Edin-burgh.	Washing-ton, I.	Washing-ton, II.	Harvard College.
	h. m. s.	s.	s.	s.	s.	s.	s.	s.	s.	s.
1858	19 39 30.54	.47	.58		.42				.15	
1859	39 33.40	.29	.84		.80				.15	
1860	39 36.25	.20	.22	.14	.14	.18	.15		.14	
1861	39 39.10	.08	.07		.00	.97	.01		.18	
1862	39 41.95	.91	.89		.76	.90	.87	.21		
1863	39 44.81	.78	.76	.69	.72	.74	.75	.20		
1864	39 47.66	.59	.59	.56	.56	.57	.58	.28		
1865	39 50.51	.44	.44	.40	.42	.58	.48	.78		
1866	39 53.86	.82	.32	.24	.80	.84	.81	.76		
1867	39 56.21		.16	.14		.17	.15	.78		
1868	39 59.07		.01	.92		.97	.03	.74		
1869	40 1.92		.88			.89	.82	.88		
1870	40 4.77		.69			.74		.76		
1871	40 7.68									.61
α Aquilæ.										
1858	19 43 51.28	.24	.26		.22				.06	
1859	43 54.21	.16	.18		.15				.06	
1860	43 57.14	.07	.15	.06	.05	.08	.08		.05	
1861	44 0.07	.01	.04		.99	.01	.00		.05	
1862	44 3.00	.92	.95		.91	.91	.91	.12		
1863	44 5.92	.86	.86	.84	.88	.91	.88	.12		
1864	44 8.85	.80	.82	.75	.79	.78	.79	.10		
1865	44 11.78	.75	.76	.66		.78	.74	.88		
1866	44 14.71	.65	.73	.62	.66	.70	.68	.44		
1867	44 17.64		.60	.55		.73	.58	.42		
1868	44 20.56		.53	.48		.52	.53	.41		
1869	44 23.49		.48			.46	.44	.46		
1870	44 26.42		.38			.38		.40		
1871	44 29.35									.31
β Aquilæ.										
1858	19 48 20.30	.23	.25		.18				.18	
1859	48 23.25	.16	.24		.18				.09	
1860	48 26.19	.09	.11	.09		.19	.09		.08	
1861	48 29.14	.08	.08		.02	.16	.10		.08	
1862	48 32.09	.06	.06		.99	.12	.08	.14		
1863	48 35.04	.96	.01	.91	.88	.94	.97	.14		
1864	48 37.98	.92	.92	.89	.88	.96	.93	.19		
1865	48 40.93	.86	.87	.85	.85	.87	.87	.62		
1866	48 43.88	.79	.82	.75	.76	.80	.80	.65		
1867	48 46.83		.79	.73		.66	.83	.63		
1868	48 49.77		.71	.68		.70	.73	.64		
1869	48 52.72		.68			.66	.68	.75		
1870	48 55.67		.60			.65		.67		
1871	48 58.62									.58

TABULAR AND OBSERVED RIGHT ASCENSIONS (*continued*).

α^2 Capricorni.		Paris.	Greenwich.	Melbourne.	Brussels.	Oxford.	Edinburgh.	Washington, I.	Washington, II.	Harvard College.
	h. m. s.	*s.*	*s.*	*s.*	*s.*	*s.*	*s.*	*s.*	*s.*	*s.*
1858	20 10 10.42	.86	.84		.88				.96	
1859	10 13.75	.74	.65		.62				.96	
1860	10 17.09	.11	.04	.00	.92	.08			.00	
1861	10 20.42	.40	.87		.29	.51			.98	
1862	10 23.76	.67	.68		.59	.72		.01		
1863	10 27.09	.00	.05	.02	.96	.06		.04		
1864	10 30.43	.89	.40	.88	.26	.81		.00		
1865	10 33.76	.70	.70	.72	.56	.65		.88		
1866	10 37.09	.04	.08	.01	.96	.04		.41		
1867	10 40.43		.40	.81		.85		.46		
1868	10 43.76		.72	.70		.70		.41		
1869	10 47.10		.06			.99				
1870	10 50.43		.40			.88		.41		
1871	10 53.77									
α Cygni.										
1858	20 36 35.52	.42	.58		.48				.55	
1859	36 37.56	.46	.51		.55				.58	
1860	36 39.61	.59	.51	.51	.54	.47			.56	
1861	36 41.65	.58	.70		.41	.71			.45	
1862	36 43.70	.59	.71		.58	.45		.59		
1863	36 45.74	.60	.71	.55	.68	.76	.72	.59		
1864	36 47.78	.66	.85	.67	.70	.78	.69	.58		
1865	36 49.83	.69	.81	.74	.71	.75		.00		
1866	36 51.87	.76	.88		.76	.76		.98		
1867	36 53.91		.84	.91		.86		.08		
1868	36 55.96		.94			.98		.99		
1869	36 58.00		.07			.89	.10	.95		
1870	37 0.05		.98			.94		.12		
1871	37 2.09									.05
α Aquarii.										
1858	21 58 29.39	.82	.88		.80				.47	
1859	58 32.47	.41	.89		.88				.47	
1860	58 35.56	.50	.50	.48	.47	.49	.52		.45	
1861	58 38.64	.56	.60		.52	.64	.58		.46	
1862	58 41.73	.68	.69		.62	.66	.67	.50		
1863	58 44.81	.78	.72	.75	.78	.72	.74	.50		
1864	58 47.89	.83	.82	.82		.85	.79	.49		
1865	58 50.98	.89	.90	.91	.86	.99	.87	.37		
1866	58 54.06	.01	.02	.02			.95	.89		
1867	58 57.15		.07	.07		.09	.07	.89		
1868	59 0.23		.17	.15		.14	.09	.40		
1869	59 3.31		.26			.26	.20	.40		
1870	59 6.40		.36			.34		.41		
1871	59 9.48									.48

TABULAR AND OBSERVED RIGHT ASCENSIONS (*continued*).

α Piscis Australis.		Paris.	Green-wich.	Mel-bourne.	Brussels.	Oxford.	Edin-burgh.	Washing-ton, I.	Washing-ton, II.	Harvard College.
	h. m. s.	s.	s.	s.	s.	s.	s.	s.	s.	s.
1858	22 49 47.80	.78	.69		.81				.85	
1859	49 51.18	.11	.05		.98				.85	
1860	49 54.46	.83	.37	.40	.37	.40			.87	
1861	49 57.80	.76	.72		.58	.70			.48	
1862	50 1.18	.19	.04		.04	.10		.41		
1863	50 4.46		.87	.89		.19		.40		
1864	50 7.79	.70	.78	.68	.64	.71		.48		
1865	50 11.12	.06	.07	.02	.09	.07		.78		
1866	50 14.45	.37	.35	.89	.32			.75		
1867	50 17.78		.71	.78		.82		.82		
1868	50 21.11		.07	.01		.10		.79		
1869	50 24.44		.37			.81				
1870	50 27.77		.78			.69		.83		
1871	50 31.09									.12
α Pegasi.										
1858	22 57 41.40	.36	.38		.27				.32	
1859	57 44.39	.36	.32		.32				.33	
1860	57 47.37	.29	.33	.29	.30	.33	.32		.28	
1861	57 50.35	.29	.34		.28	.28	.31		.29	
1862	57 53.34	.25	.35		.22	.26	.30	.35		
1863	57 56.32	.23	.23	.24	.24	.20	.23	.34		
1864	57 59.30	.22	.26	.22		.20	.27	.37		
1865	58 2.29	.22	.24	.17	.21	.23	.25	.18		
1866	58 5.27	.16	.23	.20	.21	.34	.23	.21		
1867	58 8.26		.25	.17		.25	.19	.19		
1868	58 11.24		.22	.14		.10	.20	.20		
1869	58 14.22		.14			.18	.19	.23		
1870	58 17.21		.16			.17		.22		
1871	58 20.19									.18

COMPARISON OF OBSERVED WITH TABULAR PLACES.

α Andromedæ.	Paris.	Greenwich.	Melbourne.	Brussels.	Oxford.	Edinburgh.	Washington, I.	Washington, II.	Harvard College.
	s.	s.	s.	s.	s.	s.	s.	s.	s.
1858	+.04	+.00		+.11				+.09	
1859	+.08	+.00		+.09				+.03	
1860	+.08	—.02	+.05	+.14	+.07	+.05		+.11	
1861	+.05	+.01		+.10	+.08	+.07		+.18	
1862	+.05	+.06		+.09	+.03	+.04	+.08		
1863	+.08	+.04	+.10	+.08	+.17	+.01	+.08		
1864	+.06	+.00	+.09	+.07	+.09	+.02	+.00		
1865	+.04	+.05	+.05	+.08	+.07	+.01	+.05		
1866	+.06	+.02	+ 07	+.01	+.16	+.03	+.02		
1867		+.01	+.11		+.05	+.04	+.02		
1868		+.01	+.05		—.09	+.04	+.03		
1869		+.05			+.06	+.05	+.08		
1870		+.04			+.04		+.00		
1871									+.05
Means	+.060	+.021	+.074	+.080	+.066	+.086	+.023	+.090	+.050
γ Pegasi.									
1858	+.05	+.00		+.05				+.09	
1859	+.08	+.01		+.06				+.04	
1860	+.06	+.04	+.06	+.08	+.04	+.05		+.05	
1861	+.06	+.02		+.07	—.01	—.01		+.07	
1862	+.08	+.07			+.12	+.08	+.08		
1863	+.05	+.08	+.10	+.08	+.17	+.08	+.04		
1864	+.06	+.08	+.05	+.06	+.18	+.04	+.03		
1865	+.05	+.04	+.07	+.11	+.07	+.00	+.08		
1866	+.06	+.02	+.07		+.04	+.02	—.02		
1867		+.04	+.06		+.06	+.00	+.01		
1868		+.04	+.06		+.08	+.00	—.02		
1869		+.01			+.04	+.02	+.02		
1870		+.07			—.06		—(.07)		
1871									+.01
Means	+.056	+.086	+.067	+.059	+.062	+.018	+.015	+.062	+.010
α Arietis.									
1858	+.07	+.00		+.08				+.05	
1859	+.05	+.02		+.10				+.06	
1860	+.08	+.02	+.05	+.05	+.05	+.01		+.06	
1861	+.04	+.05		+.10	+.08	+.07		+.06	
1862	+.08	+.02		+.08	+.08	+.08	+.01		
1863	+.06	—.02	+.12	+.10	+.08	+.02	+.03		
1864	+.07	+.04	+.05	+.04	+.09	+.00	+.01		
1865	+.04	+.04	+.08	+.08	+.01	+.08	+.01		
1866	+.08	+.08	+.08	+.10	+.04	+.04	+.02		
1867		+.04	+.10		—.02	+.05	+.02		
1868		+.05	+.06		—.02	+.01	+.02		
1869		+.07			—.09	+.06	+.02		
1870		+.05			—.02		+.00		
1871									+.05
Means	+.047	+.082	+.070	+.076	+.016	+.082	+.016	+.058	+.050

COMPARISON OF OBSERVED WITH TABULAR PLACES (*continued*).

α Ceti.	Paris.	Greenwich.	Melbourne.	Brussels.	Oxford.	Edinburgh.	Washington, I.	Washington, II.	Harvard College.
	s.	s.	s.	s.	s.	s.	s.	s.	s.
1858	+.04	—.01		+.14				+.06	
1859	+.02	+.01		+.06				+.05	
1860	+.05	+.06	+.06	—.03	—.02	+.00		+.06	
1861	+.03	—.01		+.05	—.05	+.08		+.08	
1862	+.08	+.04		+.12	—.04	+.07	+.00		
1863	+.06	+.08	+.05	+.03	+.06	+.04	—.02		
1864	+.00	+.08	+.03	+.01	+.08	+.09	+.01		
1865	+.02	+.02	+.08	+.03	+.01	+.05	—.01		
1866	+.02	+.02	+.04	+.01	+.04	+.09	—.01		
1867		+.04	+.04		+.02	+.07	—.00		
1868		+.01	+.04		+.06	+.07	—.08		
1869		+.06			+.09	+.07	—.08		
1870		+.05			+.09		—.04		
1871									+.08
Means	+.036	+.027	+.049	+.047	+.081	+.068	—.014	+.062	+.080
α Tauri.									
1858	+.00	+.08		+.03				+.04	
1859	+.01	+.00		+.04				+.02	
1860	+.01	+.02	+.04	+.05	+.01	+.02		+.02	
1861	+.03	—.01		+.05	+.05	+.08		+.04	
1862	+.02	+.03		+.00	+.10	+.02	—.01		
1863	+.02	+.01	+.08	+.04	+.02	+.01	—.02		
1864	+.00	+.01	+.04		—.05	+.04	+.00		
1865	+.03	+.00	+.01	+.08	—.08	—.01	+.01		
1866	+.04	+.02	+.05	+.01	—.02	+.04	+.08		
1867		+.00	+.05		+.08	+.05	+.02		
1868		+.01	+.05		—.06	+.01	+.03		
1869		+.04			+.03	+.08	+.00		
1870		+.08			+.06		+.01		
1871									+.08
Means	+.018	+.015	+.089	+.031	+.017	+.024	+.008	+.030	+.080
α Aurigæ.									
1858	—.01	+.01		+.06				+.03	
1859	—.02	—.04		+.08				+.01	
1860	—.01	—.04	—.02	+(.14)	+.04			+.04	
1861	+.02	—.0			+.08			+.07	
1862	+.07	—.01		+.01	+(.29)		+.08		
1863	—.08	+.04		+.05			—.02		
1864	—.07	—.04	+.04	+.08	—(.21)				
1865	+.02	+.06	—.02		—(.51)		+(.16)		
1866	+.13	+.02	—(.14)	+(.09)			+.02		
1867		—.08	+.06				+.10		
1868		+.04	—.05		—.08		—.05		
1869		+.04			+.06		+.08		
1870		+.11					—.08		
1871									+.07
Means	+.011	+.011	+.002	+.046	+.088		+.019	+.038	+.070

COMPARISON OF OBSERVED WITH TABULAR PLACES (*continued*).

β Orionis.	Paris.	Greenwich.	Melbourne.	Brussels.	Oxford.	Edinburgh.	Washington, I.	Washington, II.	Harvard College.
	s.	s.	s.	s.	s.	s.	s.	s.	s.
1858	—.01	+.02						—.05	
1859	—.01	+.01		+.00				—.02	
1860	—.01	+.03	+.03	—.04	+.05			—.03	
1861	—.00	+.04			+.18	+.02		—.03	
1862	—.03	+.04		+.00	—.04	+.04	+.02		
1863	—.03	+.05	+.04	+.03	+.05	+.03	+.00		
1864	—.03	+.01	+.02	+.05	—.04	+.14	+.00		
1865	—.00	+.04	+.02	—.03	—.02	+.11	+.01		
1866	—.01	+.03	+.02		—.03	+.01	+.01		
1867		—.01	+.03		+.04	+.12	+.02		
1868		+.04	+.04		—.12	+.03	+.02		
1869		+.06			+.05	+.05	—.04		
1870		+.08			+.05		—.01		
1871									+.00
Means	—.014	+.034	+.029	+.002	+.015	+.062	+.003	—.032	+.000
β Tauri.									
1858	+.05	+.02		—.03				+.12	
1859	+.03	+.02		+.01				+.07	
1860	+.01	—.06	+.01	+.00	—.08	—.09		+.06	
1861	+.04	+.03		+.09	—.08	—.07		+.12	
1862	+.04	+.06		+.02	+.08	—.00	+.00		
1863	+.06	+.00		+.01	+.04	—.01	+.03		
1864	+.02	+.00	+.06	+.04	+.01	—.01	+.03		
1865	+.07	—.01	+.03	—(.13)	+.06	—.04	+.04		
1866	+.01	+.02	+.04	—.07	+.01	—.04	+.03		
1867		+.06	+.00		+.04	—.01	+.02		
1868		+.00	+.02			+.02	+.02		
1869		+.05			+.07	—.01	+.05		
1870		+.03			+.06		+.00		
1871									+.04
Means	+.037	+.017	+.027	+.009	+.021	—.026	+.024	+.092	+.040
α Orionis.									
1858	+.00	+.04		+.05					
1859	+.05	+.00		+.04				+.04	
1860	+.04	+.00	+.03	+.08	+.02	+.10		+.05	
1861	+.04	+.08		—.01	+.06	+.06		—.01	
1862	+.03	+.04		+.00	+.05	+.01	+.00		
1863	—.01	+.03	+.02	—.01	+.02	+.03	+.00		
1864	+.00	+.01	+.01	+(.09)	+.01	+.02	+.00		
1865	+.03	—.04	+.03	+.02	+.02	+.07	—.01		
1866	+.01	+.04	+.00	+.02	—.03	+.04	+.02		
1867		+.01	—.02		—.10	+.04	+.03		
1868		+.02	+.01		+.10	+.04	+.01		
1869		+(.14)			—.12	—.01	—.01		
1870		+.06			+.05		+.03		
1871									+.00
Means	+.021	+.024	+.011	+.024	+.007	+.040	+.008	+.027	+.000

COMPARISON OF OBSERVED WITH TABULAR PLACES (*continued*).

α Canis Majoris.	Paris.	Greenwich.	Melbourne.	Brussels.	Oxford.	Edinburgh.	Washington, I.	Washington, II.	Harvard College.
	s.	s.	s.	s.	s.	s.	s.	s.	s.
1858	+.01	+.08		—.02					
1859	—.01	+.01		+.01				—.06	
1860	+.03	+.08	+.08	+.03	+.01			+.01	
1861	—.01	+.04		+.05	+(.13)			—(.11)	
1862	+.02	+.04			+.03		+.00		
1863	+.01		+.01	—.04	+.01		+.00		
1864	+.01	+.05	+.01	—.01	+(.21)		—.01		
1865	—.02	+.03	+.05	—.01			—.05		
1866	+.00	+.06	+.04		+.00		—.01		
1867		+.02	+.06		—.05		—.01		
1868		+.05	+.04				+.12		
1869		+.03			+.07		+.15		
1870		+.07			+.08		—.07		
1871									
Means	+.004	+.048	+.084	+.001	+.014		+.018	—.025	
α Canis Minoris.									
1858	+ 05	+.05		+.01				—.02	
1859	+.02	+.05		+.01				—.01	
1860	+.05	+.08	+.04	+.00	+.01	+.02		—.02	
1861	+ 08	—.01		—.01	+.06	+.06		+.01	
1862	+.04	+.08		+.01	+.04	+ 08	+.00		
1863	+.00	+.01	+.02	—(.07)	+.00	+.07	+.01		
1864	+.01	+.03	—.02	—(.17)	—.08	+.08	+.02		
1865	—.02	+.01	+.00	—.00	+.03	+.10	—.09		
1866	—.02	+.02	+.03	+.04	+.02	+.06	—.04		
1867		+.02	+.00		+.04	+.04	—.04		
1868		+.01	+.01		+.08	+.00	—.00		
1869		+.04			—.02	+.08	—.03		
1870		+.04			+.04		+.03		
1871									+.00
Means	+.018	+.026	+.011	+.009	+.020	+.044	—.016	—.010	+.000
β Geminorum.									
1858	+.04	+.01		+.05				+.04	
1859	+.03	+.01		+.08				+.00	
1860	+.02	—.02	—.01	+.05	+.02	+.06		+.03	
1861	+.04	+.03		+.04	+(.37)	—.01		+.03	
1862	+.04	+.01		+.09	— .01	—.01	—.02		
1863	+.02	+.00		—.02	+.04	—.02	—.01		
1864	+.02	+.00	+.05		+(.15)	—.01	—.03		
1865	+.00	—.02	+.04	—.04		+.02	—.02		
1866	+.01	+.04	—.01	—.04	+.07	—.04	+.04		
1867		+.04	—.01		—.02	+.00	+.01		
1868		+.02	+.01		+.08	+.00	+.02		
1869		+.03			—.08	+.00	— 01		
1870		+.01			+.00		+.01		
1871									+.01
Means	+.024	+.012	+.012	+.020	+.012	—.001	—.001	+.025	+.010

COMPARISON OF OBSERVED WITH TABULAR PLACES (*continued*).

α Hydræ.	Paris.	Greenwich.	Melbourne.	Brussels.	Oxford.	Edinburgh.	Washington, I.	Washington, II.	Harvard College.
	s.	s.	s.	s.	s.	s.	s.	s.	s.
1858	+.01	+.00		—.05					
1859	—.08	—.01		+.03				—.01	
1860	+.00	+.06	+.02	+.01	+.02	+.13		+.03	
1861	—.02	+.05		+.01	—.01			—.01	
1862	+.02	+.06		+.04	+.00	+.07	+.00		
1863	—.02	+.03	+.06	—.04	+.02		—.03		
1864	+.01	—.02	+.02	+.03		+.09	+.01		
1865	—.01	—.01	—.01	+.01	+.02	+.09	—.03		
1866	—.02	—.01	—.03	—.02	—.07		+.02		
1867		+.01	+.02		+.01	+.07	+.01		
1868		—.01	+.03		+.02		—.02		
1869		+.00			+.01	+.05	—.02		
1870		+.02			+.07		—.03		
1871									—.01
Means	—.012	+.013	+.016	+.002	+.009	+.083	—.010	+.003	—.010
α Leonis.									
1858	+.01	—.02		+.04				—.05	
1859	+.04	—.01		+.00				+.02	
1860	+.00	+.03	+.00	+.03	+.06	—.02		+.01	
1861	+.01	—.01		+.01	+.05	+.03		+.04	
1862	—.05	+.00		+.01	+.11	+.01	—.01		
1863	+.02	+.07		+.02	—.08	+.00	—.03		
1864	—.01	—.01	—.01	+.03	—.03	+.03	—.07		
1865	+.02	+.07	+.02	+.07	+.03	—.01	—.03		
1866	+.02	+.00	+.03		+.02	+.01	+.03		
1867		+.02	—.01		+.03	+.01	+.03		
1868		+.01	+.01		+.04	—.01	+.02		
1869		+.04			—.02	+.05	—.01		
1870		+.04			+.07		+.01		
1871									+.02
Means	+.007	+.018	+.007	+.026	+.025	+.010	—.007	+.005	+.020
β Leonis.									
1858	+.02	—.01		+.03					
1859	+.05	+.00		+.03				+.05	
1860	+.01	—.01	+.02	+.01	+.00	+.02		+.06	
1861	+.06	+.00		+.03	—.08	—.02		+.09	
1862	+.00	+.05		+.05	+.06	—.01	—.02		
1863	+.06	+.02		+.02	+.00	+.01	+.00		
1864	+.02	+.00	+.04	+.02	+.08	+.00	—.04		
1865	—.01	+.02	+.04	+.04	+.01	—.01	+.00		
1866	+.00	—.01	+.08	+.06	+.00	+.00	+.01		
1867		—.01	+.05		—.01	—.01	+.01		
1868		+.03	+.05		+.10	+.02	+.00		
1869		+.00			—.09	+.02	—.03		
1870		+.02			+.05		+.01		
1871									+.08
Means	+.023	+.008	+.047	+.032	+.011	+.002	—.007	+.067	+.080

COMPARISON OF OBSERVED WITH TABULAR PLACES (*continued*).

α Virginis.	Paris.	Greenwich.	Melbourne.	Brussels.	Oxford.	Edinburgh.	Washington, I.	Washington, II.	Harvard College.
	s.	s.	s.	s.	s.	s.	s.	s.	s.
1858	+.01	+.02		+.08				—.02	
1859	+.04	+.05		+.07				+.06	
1860	+.08	+.04	+.04	+.08	+.01			+.04	
1861	+.00	+.02		+ 05	—.08			+.01	
1862	+.01	+.01		+.04	—(.14)		—.01		
1863	+.00	+.08	+.08	+.10	+.00	+(.16)	—.01		
1864	—.01	+.04	+.04	+.07	+.01	+.09	—.02		
1865	—.01	+.02	+.04		—.02		—.03		
1866	+.09	+.08	+.01	+.01	—.04	+.10	—.00		
1867		+.08	+.02			+.08	—.01		
1868		+.05	+.05			+.08	—.00		
1869		+.02			+.07		—.00		
1870		+.10			—.04		+.02		
1871									+.08
Means	+.018	+.085	+.088	+.056	— .005	+.075	—.007	+.028	+.030
α Bootis.									
1858	+.08	+.02		+.06				+.07	
1859	+.08	+.01		+.07				+.08	
1860	+.04	+.02	+.06	+.06	+.08	+.00		+.08	
1861	+.06	+.08		+.04	+.01	+.04		+.11	
1862	+.11	+.08		+.02	+.05	+.05	+.01		
1863	+.08	+.04	+.05	+.11	—.02	+.01	+.02		
1864	+.08	+.00	+.10		—.09	+.02	—.01		
1865	+.07	+.04	+.10	+.04	—.08	—.03	+.02		
1866	+.06	+.04	+.08	+.04	+.04	+.08	+.08		
1867		+.08	+.05		+.01	+.02	+.02		
1868		+.05	+.07		—.03	+.00	+.08		
1869		+.05			+.01	+.02	—.01		
1870		+.08			+.05		+.02		
1871									+.02
Means	+.051	+.084	+.066	+.055	+.007	+.016	+.014	+.072	+.020
α^2 Libræ.									
1858	+.00	+.05		+.11	+.08				
1859	—.01	+.07		+.01	+.05			+.07	
1860	+.04	+.06	+.07	+.09	+.02			+.06	
1861	+.02	+.04		+.07	+.04			+.06	
1862	+.02	+.08		+.18	+.06		+.08		
1863	+.02	+.04	+.02	+.12	—.02		+.08		
1864	+.02	+.04	+.04	+.04	+.02		+.05		
1865	+.04	+.02	+.02	+.10	+.01		+.02		
1866	+.06	+.01	+.08	+.00	—.02		+.00		
1867		—.01	+.04		—.01		+.00		
1868		+.06	+.06		+.00		+.01		
1869		+.00					—.08		
1870		+.01					+.01		
1871									—.02
Means	+.028	+.082	+.040	+.074	+.016		+.018	+.063	—.020

COMPARISON OF OBSERVED WITH TABULAR PLACES (*continued*).

α CORONÆ.	Paris.	Green-wich.	Mel-bourne.	Brussels.	Oxford.	Edin-burgh.	Washing-ton, I.	Washing-ton, II.	Harvard College.
	s.	s.	s.	s.	s.	s.	s.	s.	s.
1858	+.08	+.01		+.06				+.09	
1859	+.06	+.02		+.10				+.11	
1860	+.07	+.00	+.06	+.05	+.02	—.01		+.12	
1861	+.09	+.02		+.08	+.02	+.03		+.12	
1862	+.08	+.00		+.04	+.04	—.01	+.02		
1863	+.06	+.02	+.06	+.12	—.01	—.01	+.04		
1864	+.08	+.08	+.18	+.06	+.01	—.01	—.01		
1865	+.05	+.03	+.07	+.05	+.02	—.08	+.02		
1866	+.04	+.03	+.09	+.05	+.01	—.01	+.04		
1867		+.02			+.08	+.00	+.01		
1868		+.04	+.08		—(.10)	+.01	+.04		
1869		+.03			+.01	—.01	+.00		
1870		+.06			+.00		+.01		
1871									+.04
Means	+.062	+.024	+.082	+.062	+.020	—.005	+.019	+.110	+.040
α SERPENTIS.									
1858	+.05	+.08		+.04					
1859	+.04	+.03		+.10				+.08	
1860	+.06	+.03	+.06	+.05	+.04	+.03		+.08	
1861	+.06	+.02		+.04	+.05			+.09	
1862	+.02	+.06		+.08	—.02	+.03	+.08		
1863	+.04	+.06	+.08	+.04	+.01	+.04	+.08		
1864	+.02	+.04	+.06	+.05	+.04	+.08	—(.04)		
1865	+.05	+.02	+.07	+.12	+.01	+.05	+.06		
1866	+.02	+.05	+.09		+.04	+.04	+.02		
1867		+.00	+.06		+.06	+.05	—.01		
1868		+.04	+.09		+.09	+.06	+.01		
1869		+.08			+.00	+.06	—.01		
1870		+.07			+.05		+.02		+.02
1871									
Means	+.040	+.041	+.078	+.065	+.034	+.049	+.019	+.088	+.020
α SCORPII.									
1858	+.00	+.03		+.06				—.02	
1859	—.02	+.07		+.10				+.05	
1860	—.08	+.09	+.06	+.10	+.02			+.05	
1861	—.02	+.04		+.10	+.01			+.01	
1862	—.08	+.05		+.08	+.07		+.01		
1863	—.00	—.02	+.08	+.06	+.06		+.00		
1864	—.01		+.06	+.09	+.07		+.00		
1865	—.01	+.04	+.08	+.04	—.02		+.02		
1866	+.08	—.01	+.03	+.01	—.01		—.02		
1867		+.00	+.08		—.01		—.05		
1868		+.04	+.08				+.01		
1869		+.03			—.08		—.03		
1870		+.00			+.06		+.06		
1871									+.01
Means	—.010	+.080	+.060	+.071	+.022		+.000	+.022	+.010

COMPARISON OF OBSERVED WITH TABULAR PLACES (*continued*).

α Herculis.	Paris.	Greenwich.	Melbourne.	Brussels.	Oxford.	Edinburgh.	Washington, I.	Washington, II.	Harvard College.
	s.	s.	s.	s.	s.	s.	s.	s.	s.
1858	+.05	+.05						+.07	
1859	+.04	—.07		+(.14)				+.10	
1860	+.06	+.02	+.06	+.06	+.12	+.07		+.09	
1861	+.04	+.07		+(.17)	+(.18)	+.02		+.09	
1862	+.07	—.04		+.10	+.09	—.02	+.01		
1863	+.07	+.09	+.05	+.18	+.06	+.05	+.01		
1864	+.06	—.02	+.08	+(.22)	+.03	—.01	+.08		
1865	+.04	+.02	+.11	+.10	+.03	+.04	+.02		
1866	+.04	+.01	+.09	+.13	+.07	+.03	+.01		
1867		+.01	+.11		+.08	—.01	+.01		
1868		+.04	+.08		+(.20)	+.02	+.00		
1869		+.02			+.00	+.04	—.01		
1870		+.02			+.06		+.04		
1871									+.03
Means	+.052	+.017	+.083	+.114	+.060	+.023	+.018	+.087	+.030

α Ophiuchi.	Paris.	Greenwich.	Melbourne.	Brussels.	Oxford.	Edinburgh.	Washington, I.	Washington, II.	Harvard College.
1858	+.06	+.03		+.12				+.06	
1859	+.05	+.03		+.09				+.10	
1860	+.04	+.02	+.09	+.11	+.11	+.01		+.11	
1861	+.05	+.05			+.10	+.08		+.10	
1862	+.09	+.03		+.09	+.04	+.08	+.03		
1863	+.05	—.01	+.07	+.09	+.04	+.04	+.03		
1864	+.04	+.02	+.09	+.14	+.02	+.06	+.06		
1865	+.07	+.02	+.10	+.06	+.01	+.04	+.04		
1866	+.07	+.03	+.09		+.06	+.09	+.04		
1867		+.02	+.11		+.02	+.06	+.00		
1868		+.04	+.10		+.01	+.02	+.02		
1869		+.04			+.06	+.10	+.04		
1870		+.04			—.01		+.03		
1871									+.02
Means	+.058	+.028	+.093	+.100	+.042	+.058	+.032	+.092	+.020

α Lyræ.	Paris.	Greenwich.	Melbourne.	Brussels.	Oxford.	Edinburgh.	Washington, I.	Washington, II.	Harvard College.
1858	+.07	—.03							
1859	+.08	+.06		+.03				+.14	
1860	+.08	+.07	+.08	+.09	+.04	+.02		+.15	
1861	+.06	+.08		+.03	+.13	+.09		+.17	
1862	+.12	+.04		+.11	+.07		+.03		
1863	+.08	+.02	+.04	+.04	+.11	+.02	+.04		
1864	+.10	+.03	+(.18)	+.15	—.05	+.04	+.02		
1865	+.10	+.04	+(.17)	+.10	+.06	+.07	+.04		
1866	+.12	+.03	+.10	+.10	+.02	+.06	+.02		
1867		+.03	+.10		+.09	+.04	+.01		
1868		+.04	+.09		—.04	+.04	+.04		
1869		+.04			+.07	+.03	+.01		
1870		+.08			+.08		+.03		
1871									+.03
Means	+.090	+.037	+.082	+.081	+.058	+.046	+.027	+.153	+.030

COMPARISON OF OBSERVED WITH TABULAR PLACES (*continued*).

γ Aquilæ.	Paris.	Green-wich.	Mel-bourne.	Brussels.	Oxford.	Edin-burgh.	Washing-ton, I.	Washing-ton, II.	Harvard College.
	s.	*s.*	*s.*	*s.*	*s.*	*s.*	*s.*	*s.*	*s.*
1858	+.07	+.01		+.12				+.10	
1859	+.11	+.06		+.10				+.10	
1860	+.05	+.08	+.11	+.11	+.12	+.10		+.11	
1861	+.07	+.08		+.10	+.13	+.09		+.12	
1862	+.04	+.06		+(.19)	+.05	+.08	+.04		
1863	+.08	+.05	+.12	+.09	+.07	+.06	+.05		
1864	+.07	+.07	+.10	+.10	+.09	+.08	+.02		
1865	+.07	+.07	+.11	+.09	—.02	+.03	+.04		
1866	+.04	+.04	+.12	+.06	+.02	+.05	+.01		
1867		+.05	+.07		+.04	+.06	+.04		
1868		+.06	+.15		+.10	+.04	+.03		
1869		+.04			+.03	+.10	—.06		
1870		+.08			+.03		+.01		
1871									+.02
Means	+.067	+.050	+.111	+.096	+.060	+.069	+.020	+.108	+.020
α Aquilæ.									
1858	+.04	+.02		+.06				+.08	
1859	+.05	+.03		+.06				+.08	
1860	+.07	—.01	+.08	+.09	+.06	+.11		+.09	
1861	+.06	+.03		+.08	+.06	+.07		+.09	
1862	+.08	+.05		+.09	+.09	+.09	+.02		
1863	+.06	+.06	+.08	+.09	+.01	+.04	+.02		
1864	+.05	+.03	+.10	+.06	+.07	+.06	+.04		
1865	+.03	+.02	+.12		+.00	+.04	+.04		
1866	+.06	—.02	+.09	+.05	+.01	+.03	—.02		
1867		+.04	+.09		—(.09)	+.06	+.00		
1868		+.03	+.08		+.04	+.03	+.01		
1869		+.01			+.03	+.05	—.04		
1870		+.04			+.04		+.02		
1871									+.04
Means	+.056	+.025	+.091	+.073	+.041	+.058	+.010	+.085	+.040
β Aquilæ.									
1858	+.07	+.05		+.12				+.06	
1859	+.09	+.01		+.12				+.10	
1860	+.10	+.08	+.10		+.00	+.10		+.11	
1861	+.06	+.06		+.12	—.02	+.04		+.11	
1862	+.03	+.03		+.10	—.03	+.06	+.05		
1863	+.08	+.03	+.13	+(.16)	+.10	+.07	+.05		
1864	+.06	+.06	+.09	+.10	+.02	+.05	+.00		
1865	+.07	+.06	+.08	+.08	+.06	+.06	+.05		
1866	+.09	+.06	+.13	+.12	+.08	+.08	+.02		
1867		+.04	+.10		+.17	+.00	+.04		
1868		+.06	+.09		+.07	+.04	+.03		
1869		+.04			+.06	+.04	—.08		
1870		+.07			+.02		+.00		
1871									+.04
Means	+.072	+.050	+.103	+.109	+.048	+.054	+.018	+.095	+.040

COMPARISON OF OBSERVED WITH TABULAR PLACES (*continued*)

a^2 Capricorni.	Paris.	Greenwich.	Melbourne.	Brussels.	Oxford.	Edinburgh.	Washington, I.	Washington, II.	Harvard College.
	s.	s.	s.	s.	s.	s.	s.	s.	s.
1858	+.06	+.08		+.04				+.13	
1859	+.01	+.10		+.13				+.18	
1860	—.02	+.05	+.09	+.17	+.01		+.08	+.09	
1861	+.02	+.05		+ 18	—.09		+.05	+.11	
1862	+.09	+.08		+.17	+.04		+.09		
1863	+.09	+.04	+.07	+.13	+.08		+.05		
1864	+.04	+.03	+.05	+.17	+.12		+.02		
1865	+.06	+.06	+.04	+.20	+.11		—.03		
1866	+.05	+.01	+.08	+.13	+.05		+.02		
1867		+.08	+.12		+.08				
1868		+.04	+.06		+.06		+.02		
1869		+.04			+.11				
1870		+.03			+.05				
1871									
Means	+.044	+.049	+.078	+.141	+.052		+.088	+.115	
a Cygni.									
1858	+.10	—.01		+.04				+.06	
1859	+.10	+.05		+.01				+.08	
1860	+.02	+.10	+.10	+.07	+.14			+.05	
1861	+.07	—(.05)		+(.24)	—.06			+.16	
1862	+.11	—.01		+.12	+(.25)		+.02		
1863	+(.14)	+.08	+.19	+.06	—.02	+.02	+.02		
1864	+.12	—(.07)	+.11	+.08	+.05	+.09	+.03		
1865	+(.14)	+.02	+.09	+.12	+.08		+.05		
1866	+.11	+.04		+.11	+.11		+.07		
1867		+.07	+.00		+.05		—.03		
1868		+.02			+.08		+.06		
1869		—(.07)			+.11	—(.10)	+.10		
1870		+.07			+.11		—.07		
1871									+.04
Means	+.090	+.088	+.098	+.076	+.060	+.055	+.028	+.075	+.040
a Aquarii.									
1858	+.07	+.06		+.09				+.09	
1859	+.06	+.08		+.09				+.09	
1860	+.06	+.06	+.08	+.09	+.07	+.04		+.11	
1861	+.08	+.04		+.12	+.00	+.06		+.10	
1862	+.05	+.04		+.11	+.07	+.06	+.06		
1863	+.08	+.09	+.06	+.08	+.09	+.07	+.06		
1864	+.06	+.07	+.07		+.04	+.10	+.07		
1865	+.09	+.08	+.07	+.12	—.01	+.11	+.08		
1866	+.05	+.04	+.04			+.11	+.01		
1867		+.08	+.08		+.06	+.08	+.01		
1868		+.06	+.08		+.09	+.14	+.00		
1869		+.05			+.05	+.11	+.00		
1870		+.04			+.06		—.01		
1871									+.00
Means	+.067	+.061	+.069	+.100	+.052	+.088	+.026	+.098	+.000

COMPARISON OF OBSERVED WITH TABULAR PLACES (*continued*).

α Piscis Australis.	Paris.	Greenwich.	Melbourne.	Brussels.	Oxford.	Edinburgh.	Washington, I.	Washington, II.	Harvard College.
	s.	*s.*	*s.*	*s.*	*s.*	*s.*	*s.*	*s.*	*s.*
1858	+.07	+.11		—.01				+.11	
1859	+.02	+.08		+(.20)				+.11	
1860	+.18	+.09	+.06	+.09	+.06			+.09	
1861	+.04	+.08		+(.22)	+.10			+.03	
1862	—(.06)	+.09		+.09	+.03		+.05		
1863		+.09	+.07		+(.27)		+.06		
1864	+.09	+.01	+.11	+.15	+.08		+.03		
1865	+.06	+.05	+.10	+.03	+.05		—.01		
1866	+.08	+.10	+.06	+.18			+.02		
1867		+.07	+.05		—.04		—.05		
1868		+.04	+.10		+.01		—.02		
1869		+.07			+.13				
1870		+.04			+.08		—.06		
1871									—.03
Means	+.070	+.071	+.079	+.080	+.056		+.002	+.085	—.030
α Pegasi.									
1858	+.04	+.02		+.18				+.05	
1859	+.03	+.07		+.07				+.04	
1860	+.08	+.04	+.08	+.07	+.04	+.05		+.09	
1861	+.06	+.01		+.07	+.07	+.04		+.08	
1862	+.09	—.01		+.12	+.08	+.04	+.02		
1863	+.09	+.09	+.08	+.08	+.12	+.04	+.03		
1864	+.08	+.04	+.08		+.10	+.03	+.00		
1865	+.07	+.05	+.12	+.08	+.06	+.04	+.08		
1866	+.11	+.04	+.07	+.06	—.07	+.04	+.00		
1867		+.01	+.09		+.01	+.07	+.02		
1868		+.02	+.10		+.14	+.04	+.01		
1869		+.08			+.04	+.03	—.02		
1870		+.05			+.04		—.01		
1871									+.01
Means	+.072	+.089	+.089	+.085	+.057	+.042	+.009	+.065	+.010

The following tables contain: —

TABLE I.

The residuals, in thousandths of seconds, obtained by subtracting the observed from the computed places, after applying, in each case, the correction for equinox, ε, which is obtained by dividing the difference between the sum of the positive and the negative corrections by 30, the number of stars employed. In the first approximation, neither α Canis Majoris nor α Piscis Australis will be used, the results for these stars being included in brackets.

		s.
For Greenwich	$\varepsilon =$	+.029
Washington, I.	=	+.011
Washington, II.	=	+.062
Paris	=	+.089
Melbourne	=	+.057
Brussels	=	+.061
Oxford	=	+.082
Edinburgh	=	+.039
Harvard College	=	+.023

The sum of the residuals for each observatory is designated by $[v]$.

TABLE II.

The residuals, arranged in order of declination, obtained by subtracting from the residuals in Table I. the periodic errors of single period, derived from the following normal equations for the mean date 1864: —

		s.	s.
For Greenwich . . .	$17.58\,m + .26\,n = \Sigma\,r \sin a$	$= -.189$	$m = -.011$
	$.26\,m + 12.82\,n = \Sigma\,r \cos a$	$= +.100$	$n = +.008$
For Washington, I. . .	$17.58\,m + .26\,n = \Sigma\,r \sin a$	$= -.159$	$m = -.009$
	$.26\,m + 12.82\,n = \Sigma\,r \cos a$	$= +.119$	$n = +.010$
For Washington, II. . .	$17.58\,m + .26\,n = \Sigma\,r \sin a$	$= -.640$	$m = -.037$
	$.26\,m + 12.82\,n = \Sigma\,r \cos a$	$= +.247$	$n = +.021$
For Paris	$17.58\,m + .26\,n = \Sigma\,r \sin a$	$= -.379$	$m = -.022$
	$.26\,n + 12.82\,n = \Sigma\,r \cos a$	$= +.266$	$n = +.022$
For Melbourne . . .	$17.58\,m + .26\,n = \Sigma\,r \sin a$	$= -.598$	$m = -.034$
	$.26\,n + 12.82\,n = \Sigma\,r \cos a$	$= +.249$	$n = +.021$
For Brussels	$17.58\,m + .26\,n = \Sigma\,r \sin a$	$= -.661$	$m = -.038$
	$.26\,n + 12.32\,n = \Sigma\,r \cos a$	$= +.252$	$n = +.021$
For Oxford	$17.58\,m + .26\,n = \Sigma\,r \sin a$	$= -.226$	$m = -.013$
	$.26\,n + 12.82\,n = \Sigma\,r \cos a$	$= +.262$	$n = +.022$
For Edinburgh . . .	$14.67\,m - .89\,n = \Sigma\,r \sin a$	$= -.186$	$m = -.009$
	$.89\,m + 11.28\,n = \Sigma\,r \cos a$	$= +.107$	$n = +.010$
For Harvard College .	$16.87\,m + .71\,n = \Sigma\,r \sin a$	$= -.019$	$m = -.001$
	$.71\,m + 12.03\,n = \Sigma\,r \cos a$	$= +.106$	$n = +.009$

TABLE I.

	δ	Green-wich.	Wash'g-ton, I.	Wash'g-ton, II.	Paris.	Mel-bourne.	Brus'ls.	Oxford.	Edin-burgh.	Harv'd College.
	°									
α Andromedæ . .	....	−8	+12	+28	+21	+17	+19	+34	−3	+27
γ Pegasi	....	+7	+4	+0	+17	+10	−2	+30	−21	−13
α Arietis	....	+3	+5	−4	+8	+13	+15	−16	−7	+27
α Ceti	....	−2	−25	+0	−3	−8	−14	−1	+24	+7
α Tauri	....	−14	−3	−32	−21	−18	−30	−15	−15	+7
α Aurigæ	....	−18	+8	−24	−28	−55	−15	+6	....	+47
β Orionis	....	+5	−8	−94	−53	−28	−59	−17	+23	−23
β Tauri	....	−12	+13	+30	−2	−30	−52	−11	−65	+17
α Orionis	....	−5	−3	−35	−18	−46	−37	−25	+1	−23
[α Canis Majoris .	....	+14	+2	−87	−35	−23	−60	−18	....	....]
α Canis Minoris .	....	−3	−27	−72	−21	−46	−52	−12	+5	−23
β Geminorum . .	....	−17	−12	−37	−15	−45	−41	−20	−40	−13
α Hydræ	....	−16	−21	−59	−51	−41	−59	−23	+44	−33
α Leonis	....	−11	−18	−57	−32	−50	−35	−7	−29	−3
β Leonis	....	−21	−18	+5	−16	−10	−29	−21	−37	+7
α Virginis . . .	....	+6	−18	−37	−21	−24	−5	−37	+39	+7
α Bootis	....	+5	+3	+10	+12	+9	−6	−25	−23	−3
α² Libræ	....	+3	+2	+1	−16	−17	+13	−16	....	−43
α Coronæ	....	−5	+8	+48	+23	+25	+1	−12	−44	+17
α Serpentis . . .	....	+12	+8	+21	+1	+16	+4	+2	+10	−3
α Scorpii	....	+1	−11	−40	−49	+3	+10	−10	....	−13
α Herculis . . .	....	−12	+2	+25	+13	+26	+53	+28	−16	+7
α Ophiuchi . . .	....	−1	+21	+30	+19	+36	+39	+10	+14	−3
α Lyræ	....	+8	+16	+91	+51	+25	+20	+21	+7	+7
γ Aquilæ	....	+21	+9	+46	+28	+54	+35	+28	+30	−3
α Aquilæ	....	−4	−1	+23	+17	+34	+12	+9	+19	+17
β Aquilæ	....	+21	+7	+33	+33	+46	+48	+16	+15	+17
α² Capricorni . .	....	+20	+27	+53	+5	+16	+80	+20	....	....
α Cygni	....	+9	+17	+13	+51	+41	+15	+28	+16	+17
α Aquarii. . . .	....	+32	+15	+36	+28	+12	+39	+20	+49	−23
[α Piscis Australis	....	+42	−9	+23	+31	+22	+19	+24	....	−53]
α Pegasi	....	+10	−2	+3	+33	+32	+24	+25	+3	−13
[v]		+163 −149	+177 −167	+496 −491	+360 −346	+415 −418	+427 −436	+277 −268	+299 −300	+228 −235

TABLE II.

[α Piscis Australis	−30°.3	+31	−21	−7	+3	−8	−12	−1	....	−62]
α Scorpii	−26.1	−6	−15	−66	−60	−19	−16	−13	....	−10
[α Canis Majoris .	−16.5	+25	+13	−47	−9	+15	−18	−1	....	....]
α² Libræ	−15.5	+2	+4	−8	−13	−23	+4	−7	....	−37
α² Capricorni . .	−12.9	+7	+14	+11	−25	−24	+37	−3	....	....
α Virginis . . .	−10.5	+10	−12	−30	−7	−15	+2	−20	+42	+15
β Orionis	−8.3	+14	−1	−62	−37	+0	−31	−9	+29	−24
α Hydræ	−8.1	−3	−7	−20	−20	−3	−19	+2	+58	−25
α Aquarii. . . .	−1.0	+20	+3	+1	−2	−23	+2	−5	+37	−31
α Ceti	+3.6	+0	−26	+11	−5	+0	−3	+6	+23	+2
α Canis Minoris .	+5.6	+10	−15	−30	+8	−7	−9	+9	+17	−18
β Aquilæ	+6.1	+7	−6	−9	+3	+6	+11	−6	+2	+12
α Serpentis . . .	+6.8	+8	+7	+3	−4	+0	−15	+4	+9	+1
α Orionis	+7.4	+6	+6	+1	+4	−13	+0	−13	+10	−22
α Aquilæ	+8.5	−18	−13	−19	−12	−6	−31	−13	+7	+12
γ Aquilæ	+10.3	+8	−3	+4	−1	+14	−9	+7	+18	−8
α Leonis	+12.6	+2	−5	−22	−2	−15	+2	+18	−16	+6
α Ophiuchi . . .	+12.7	−11	+13	−4	+0	+5	+4	+0	+6	−3
γ Pegasi	+14.5	−1	−6	−19	−6	−10	−22	+8	−31	−22
α Pegasi	+14.5	−1	−14	−26	+6	+3	−6	+1	−9	−22
α Herculis . . .	+14.5	−21	−5	−7	−3	−2	+21	+20	−23	+8
β Leonis	+15.3	−12	−7	+28	+8	+14	−5	+2	−26	+16
α Tauri	+16.2	−8	+1	−6	−10	+5	−3	−12	−11	+4
α Bootis	+19.9	+6	+6	+7	+19	+9	−9	−13	−20	+4
α Arietis	+22.8	+1	+0	−3	+0	+12	+16	−29	−12	+20
α Coronæ	+27.2	−9	+7	+31	+19	+11	−16	−9	−45	+21
α Andromedæ . .	+28.3	−16	+2	+8	−1	−4	−2	+12	−13	+18
β Geminorum . .	+28.4	−4	+0	+5	+14	−6	+3	+1	−28	−8
β Tauri	+28.5	−2	+20	+62	+16	−1	−19	−2	−58	+16
α Lyræ	+38.7	−4	+6	+51	+26	−12	−21	+5	−3	+5
α Cygni	+44.8	−5	+4	−29	+20	+1	−28	+4	+3	+10
α Aurigæ	+46.0	−9	+15	+7	−12	−27	+17	+14	....	+46
[v]		+101 −130	+108 −135	+230 −360	+143 −220	+80 −210	+119 −264	+113 −154	+261 −295	+216 −230

It is quite obvious, from simple inspection, that in the case of Paris, Edinburgh, Washington II., and Harvard College, the corrections depending on the Declination are quite large, while in every other case they are of sufficient magnitude to be recognizable.

For each residual, r'', of Table II., there will be an equation of the form:—

$$r'' = a \sin \delta + b \cos \delta,$$

from which a and b are to be found.

For a first approximation it will be allowable to arrange the equations in groups, in each of which r'', $\sin \delta$ and $\cos \delta$ are understood to be mean values. The following are the limits of the groups:—

Group I.	from $-30°$ to $-8°$
Group II.	from $-1°$ to $+10°$
Group III.	from $+12°$ to $+23°$
Group IV.	from $+27°$ to $+46°$

α Piscis Australis and α Canis Majoris will now be included in the discussion.

EQUATIONS.

		Greenwich.	Washington, I.	Washington, II.	Paris.	Melbourne.	Brussels.	Oxford.
Group I.	$-.27\,a + .95\,b =$	$+10$	-4	-29	-21	-10	-7	-6
Group II.	$+.10\,a + .99\,b =$	$+5$	-5	-5	-1	-4	-7	-1
Group III.	$+.27\,a + .96\,b =$	-5	-3	-6	$+1$	$+2$	$+0$	$+0$
Group IV.	$+.56\,a + .88\,b =$	-6	$+8$	$+19$	$+12$	-5	-9	$+3$

	Edinburgh.	Harvard College.
Group I.	$-.15\,a + .99\,b = +13$	$-.28\,a + 95\,b = -24$
Group II.	$+.10\,a + .99\,b = +15$	$+.10\,a + 99\,b = -7$
Group III.	$+.27\,a + .96\,b = -16$	$+.27\,a + 96\,b = +1$
Group IV.	$+.53\,a + .85\,b = -24$	$+.56\,a + 88\,b = +15$

From these equations, we have by least-squares the following values of a and b:—

	s.	s.
For Greenwich	$a = -.021$	$b = +.005$
Washington, I.	$a = +.015$	$b = -.005$
Washington, II.	$a = +.056$	$b = -.016$
Paris	$a = +.039$	$b = -.009$
Melbourne	$a = +.008$	$b = -.006$
Brussels	$a = -.005$	$b = -.004$
Oxford	$a = +.013$	$b = -.004$
*Edinburgh	$a = -.101$	$b = +.025$
Harvard College	$a = +.044$	$b = -.014$

Computing the values of r'' with these coefficients, and subtracting from the residuals of Table II., we have Table III., arranged in order of Right Ascensions.

* The discussion of a series of equations of the form $r'' = a \frac{\sin z}{\cos \delta} + b \frac{\cos z}{\cos \delta} + \frac{c}{\cos \delta}$ gave results nearly identical with these.

TABLE III.

	Green-wich.	Wash'g-ton, I.	Wash'g-ton, II.	Paris.	Mel-bourne.	Bruss'ls.	Oxford.	Edin-burgh.	Harv'd College.
α Andromedæ	−10	−1	−4	−11	−3	+4	+10	+12	+9
γ Pegasi	−1	−5	−17	−7	−6	−17	+9	−30	−19
α Arietis	+4	−1	−10	−7	+15	+22	−30	+4	+16
α Ceti	−4	−22	+24	+2	+6	+1	+9	+4	+13
α Tauri	−7	+2	−7	−12	+9	+2	−12	−7	+5
α Aurigæ	+3	+7	−22	−34	−29	+24	+8	....	+22
β Orionis	+6	+6	−38	−23	+7	−28	−3	−10	−4
β Tauri	+4	+17	+50	+6	+0	−13	−4	−33	+7
α Orionis	+4	+9	+10	+8	−8	+5	−11	−2	−14
α Canis Majoris	+14	+22	−16	+11	+23	−15	+7	....	....
α Canis Minoris	+7	−12	−20	+13	−2	−5	+12	+2	−8
β Geminorum	+2	−3	−7	+4	−5	+9	−1	−3	−18
α Hydræ	−11	+10	+4	−6	+4	−16	+8	+19	−5
α Leonis	+2	−3	−18	−2	−11	+7	+19	−19	+10
β Leonis	−12	−6	+28	+7	+18	+0	+3	−24	+19
α Virginis	+1	−4	−4	+9	−8	+5	−14	−1	+37
α Bootis	+8	+6	+3	+15	+12	−3	−13	−10	+2
α² Libræ	−9	+13	+22	+7	−15	+7	+0	....	−12
α Coronæ	−3	+5	+19	+9	+12	−10	−11	−21	+13
α Serpentis	+6	+10	+12	+0	+5	−10	+6	−4	+10
α Scorpii	−19	−4	−27	−35	−11	−14	−3	....	+22
α Herculis	−21	−4	−5	−4	+2	+26	+21	−22	+11
α Ophiuchi	−11	+15	+0	+0	+9	+9	+1	+3	+1
α Lyræ	+5	+1	+30	+9	−11	−14	+1	+39	−11
γ Aquilæ	+7	−1	+10	+1	+18	−4	+9	+11	−2
α Aquilæ	−20	−10	−11	−9	−1	−26	−11	−3	+19
β Aquilæ	+4	−3	+1	+8	+11	+15	−3	−12	+20
α² Capricorni	−3	+22	+39	−7	−16	+40	+4	....	....
α Cygni	+6	−2	−57	−1	−1	−21	−2	+56	−11
α Aquarii	+15	+8	+18	+8	−17	+5	−1	−10	−17
α Piscis Australis	+17	−10	+35	+30	+1	−11	+8	....	−28
α Pegasi	−1	−13	−24	+5	+7	−1	+2	−8	−19
[v]	+115 −132	+143 −104	+305 −287	+152 −158	+159 −144	+181 −208	+137 −119	+150 −219	+236 −168

The assignment of weights to observations is necessarily somewhat a matter of individual judgment. The following empirical formula, though not free from objection, will be adopted: —

Let w' = the quotient obtained by dividing the square root of the number of years of observation for any observatory, by $\sqrt{13}$.

w'' = the quotient obtained by dividing 10 $[v\,v]$ for Greenwich by $[v\,v]$ for any other observatory.

Then the weight,
$$w = \frac{w' + w''}{2}.$$

By this formula we have, after increasing the values for Edinburgh and Harvard College proportionately, —

	$[v\,v]$	w''	w'	w
For Greenwich	2941	10.0	10.0	10
Washington, I.	3168	9.3	8.3	9
Washington, II.	17172	1.7	2.0	2
Paris	5490	5.4	8.3	7
Melbourne	4331	6.8	7.2	7
Brussels	7509	3.9	8.3	6
Oxford	3418	8.6	9.2	9
Edinburgh	13023	2.3	8.9	6
Harvard College	7834	3.8	1.0	2

Assigning to the residuals in Table III. the weights w, and taking the means, we have (omitting for the present the discussion of errors of double period) the following system of corrections, as shown in Table IV.

TABLE IV.

	Assumed correction to Newcomb.	Derived correction to assumed R. A.	Derived correction to Newcomb.	Adopted correction to Newcomb.
α Andromedæ	+ 0	+ 0	+ 0	− 3
γ Pegasi	−10	+ 7	− 3	− 6
α Arietis	+ 0	+ 0	+ 0	− 3
α Ceti	+ 0	+ 0	+ 0	− 3
α Tauri	+ 0	+ 4	+ 4	+ 1
α Aurigæ	−20	+ 2	−18	−21
β Orionis	+10	+ 6	+16	+13
β Tauri	+10	− 1	+ 9	+ 6
α Orionis	+10	− 1	+ 9	+ 6
α Canis Majoris	+20	−10	+10	+ 7
α Canis Minoris	+10	− 1	+ 9	+ 6
β Geminorum	+ 0	+ 1	+ 1	− 2
α Hydræ	+ 0	+ 1	+ 1	− 2
α Leonis	+ 0	+ 0	+ 0	− 3
β Leonis	+ 0	+ 0	+ 0	− 3
α Virginis	+ 0	+ 1	+ 1	− 2
α Bootis	+10	− 3	+ 7	+ 4
α^2 Libræ	+10	− 1	+ 9	+ 6
α Coronæ	+ 0	+ 1	+ 1	− 2
α Serpentis	+10	− 3	+ 7	+ 4
α Scorpii	−10	+13	+ 3	+ 0
α Herculis	+ 0	+ 1	+ 1	− 2
α Ophiuchi	+10	− 3	+ 7	+ 4
α Lyræ	+ 0	− 4	− 4	− 7
γ Aquilæ	+10	− 6	+ 4	+ 1
α Aquilæ	−10	+10	+ 0	− 3
β Aquilæ	+10	− 3	+ 7	+ 4
α^2 Capricorni	+10	− 6	+ 4	+ 1
α Cygni	−10	− 1	−11	−14
α Aquarii	+10	− 2	+ 8	+ 5
α Piscis Australis	+20	− 6	+14	+11
α Pegasi	+ 0	+ 3	+ 3	+ 0
[v]	+160 − 60	+50 −51	+135 − 36	+79 −76

The accidental errors of the standard catalogue, as indicated by modern observations, are now sufficiently well known to enable us to make a final determination of all the periodic coefficients. In this final discussion, the approximate corrections depending on the Declination, already found, will be applied before the solution of the equations of the form

$$m \sin a + n \cos a = r.$$

The values of m and n should not differ much from those already found; since the errors depending on the Declination are largely eliminated. Thus, *e.g.*, the error for α Canis Majoris is counterbalanced by that for α Aurigæ, and the error for α Piscis Australis by that for α Cygni.

The method of procedure will be the same as before. The residuals given on page 148 and following, are first corrected by the values given in the last column of Table IV. Including α Canis Majoris and α Piscis Australis, the following are the values of e, to be applied to the observations:—

	s.
For Greenwich	$\epsilon = +.028$
Washington, I.	$= +.008$
Oxford	$= +.029$
Paris	$= +.036$
Melbourne	$= +.054$
Edinburgh	$= +.036$
Brussels	$= +.056$
Washington, II.	$= +.057$
Harvard College	$= +.019$

Subtracting the values of ϵ, we have Table V.

Table VI. is formed by subtracting from the residuals in Table V. the provisional corrections depending on the Declination, already obtained. From the residuals of Table VI. are found the following periodic equations of single period:—

For Greenwich	$r = -\overset{s.}{.007} \sin a + \overset{s.}{.011} \cos a.$
Washington, I.	$r = -.009 \sin a + .007 \cos a.$
Oxford	$r = -.014 \sin a + .021 \cos a.$
Paris	$r = -.024 \sin a + .021 \cos a.$
Melbourne	$r = -.034 \sin a + .021 \cos a.$
Edinburgh	$r = -.018 \sin a + .016 \cos a.$
Brussels	$r = -.039 \sin a + .022 \cos a.$
Washington, II.	$r = -.042 \sin a + .019 \cos a.$
Harvard College	$r = -.003 \sin a + .002 \cos a.$

Computing the values of r for each star, and subtracting from the residuals in Table VI., we have Table VII.

From the residuals of Table VII., we have the following normal equations for the more accurate determination of a and b:—

	Greenwich.	Wash. I.	Oxford.	Paris.	Melbourne.	Brussels.	Wash. II.
$8.79\,\Delta a + 4.38\,\Delta b = \Sigma\, r'' \sin\delta =$	-19	$+6$	-9	-18	$+0$	$+20$	-17
$4.38\,\Delta a + 28.29\,\Delta b = \Sigma\, r'' \cos\delta =$	-76	$+34$	$+1$	-2	$+21$	$+34$	$+81$

Edinburgh.	Harvard College.
$2.68\,\Delta a + 5.45\,\Delta b = \Sigma\, r'' \sin\delta = 0$	$8.66\,\Delta a + 4.86\,\Delta b = \Sigma\, r'' \sin\delta = +34$
$5.45\,\Delta a + 23.48\,\Delta b = \Sigma\, r'' \cos\delta = -88$	$4.86\,\Delta a + 26.48\,\Delta b = \Sigma\, r'' \cos\delta = +115$

Whence:

	s.	s.
For Greenwich	$\Delta a = -.003$	$\Delta b = -.002$
Washington, I.	$= +.001$	$= +.001$
Oxford	$= -.002$	$= +.000$
Paris	$= -.005$	$= +.001$
Melbourne	$= -.001$	$= +.001$
Edinburgh	$= +.014$	$= -.007$
Brussels	$= +.004$	$= +.001$
Washington, II.	$= -.009$	$= +.004$
Harvard College	$= +.004$	$= +.004$

Subtracting the values of r, computed with these coefficients, from the residuals of Table VII., we have Table VIII.

From the residuals of Table VIII., we have the following normal equations for determining the periodic coefficients for errors of double period: —

	Green-wich.	Wash. I.	Oxford.	Paris.	Mel-bourne.	Brus-sels.	Wash. II.
$15.70m' - .41n' = \Sigma r' \sin 2a =$	-19	$+89$	-74	-22	$+32$	$+42$	$+79$
$.41m' + 16.28n' = \Sigma r' \cos 2a =$	$+15$	-77	$+5$	$+77$	$+12$	$+15$	$+23$

Edinburgh.

$$12.64\,m' - .61\,n' = \Sigma\, r' \sin 2a = -86$$
$$.61\,m' + 18.83\,n' = \Sigma\, r' \cos 2a = -87$$

Harvard College.

$$14.75\,m' + .28\,n' = \Sigma\, r' \sin 2a = +121$$
$$.28\,m' + 15.22\,n' = \Sigma\, r' \cos 2a = -26$$

Whence:

		s.	s.
For Greenwich	m'	$= -.001$	$n' = +.001$
Washington, I.		$= +.002$	$= -.005$
Oxford		$= -.005$	$= +.000$
Paris		$= -.001$	$= +.005$
Melbourne		$= +.002$	$= +.001$
Edinburgh		$= -.007$	$= -.002$
Brussels		$= +.008$	$= +.001$
Washington, II.		$= +.005$	$= +.001$
Harvard College		$= +.008$	$= -.002$

Subtracting the values of r', computed with the coefficients m' and n', from the residuals of Table VIII., we have finally Table IX., containing the final corrections to the assumed places.

TABLE V.

	Green-wich.	Wash'g-ton, I.	Oxford.	Paris.	Mel-bourne.	Edin-burgh.	Brus's'ls.	Wash'g-ton, II.	Harv'd College.
α Andromedæ	−10	+12	+34	+21	+17	− 3	+21	+30	+28
γ Pegasi	+12	+11	+37	+24	+17	−14	+ 7	+ 9	− 5
α Arietis	+ 1	+ 5	−16	+ 8	+13	− 7	+17	− 2	+28
α Ceti	− 4	−25	− 1	− 3	− 8	+24	−12	+ 2	+ 8
α Tauri	−12	+ 1	−11	−17	−14	−11	−24	−26	+12
α Aurigæ	−18	+10	+ 8	−26	−53	....	−11	−20	+50
β Orionis	+ 9	− 2	−11	−47	−22	+29	−51	−86	−16
β Tauri	−15	+12	−12	− 3	−31	−66	−51	+31	+17
α Orionis	− 8	− 4	−26	−19	−47	+ 0	−36	−34	−23
α Canis Majoris	+ 2	− 8	−28	−45	−33	....	−68	−95	....
α Canis Minoris	− 6	−28	−13	−22	−47	+ 4	−51	−71	−23
β Geminorum	−18	−11	−19	−14	−44	−39	−38	−34	−11
α Hydræ	−17	−20	−22	−50	−40	+45	−56	−56	−31
α Leonis	−13	−18	− 7	−32	−50	−29	−33	−55	− 2
β Leonis	−23	−18	−21	−16	−10	−37	−27	+ 7	+ 8
α Virginis	+ 5	−17	−36	−20	−23	+37	− 2	−36	+ 9
α Bootis	+ 0	− 0	−28	+ 9	+ 6	−26	− 7	+ 9	− 5
α^2 Libræ	+ 0	+ 1	−17	−17	−18	....	+14	+ 2	−43
α Coronæ	− 6	+ 9	−11	+24	+26	−43	+ 4	+51	+19
α Serpentis	+ 7	+ 5	− 1	− 2	+13	+ 7	+ 3	+20	− 5
α Scorpii	+12	+ 2	+ 3	−36	+16	....	+25	−25	+ 1
α Herculis	−13	+ 3	+29	+14	+27	−15	+56	+28	+ 9
α Ophiuchi	− 6	+18	+ 7	+16	+33	+11	+38	+29	− 5
α Lyræ	+ 2	+12	+17	+47	+21	+ 3	+18	+89	+ 4
γ Aquilæ	+13	+ 3	+22	+22	+48	+24	+31	+42	− 8
α Aquilæ	+ 4	+ 9	+19	+27	+44	+29	+24	+35	+28
β Aquilæ	+ 6	+ 4	+13	+30	+43	+12	+47	+32	+15
α^3 Capricorni	+12	+21	+14	− 1	+10	....	+76	+49	....
α Cygni	+ 6	+16	+27	+50	+40	+15	+16	+14	+17
α Aquarii	+28	+13	+18	+26	+10	+47	+39	+36	−24
α Piscis Australis	+34	−15	+18	+25	+16	....	+15	+19	−58
α Pegasi	+11	+ 1	+28	+36	+35	+ 6	+29	+ 8	− 9
[v]	+166 −169	+168 −166	+294 −280	+379 −370	+435 −440	+293 −290	+480 −467	+542 −540	+253 −268

TABLE VI.

	Green-wich.	Wash'g-ton, I.	Oxford	Paris.	Mel-bourne.	Edin-burgh.	Bruss'ls.	Wash'g-ton, II.	Harv'd College.
α Andromedæ	−4	+9	+32	+11	+18	+22	+27	+18	+19
γ Pegasi	+12	+12	+38	+22	+21	−13	+12	+11	−2
α Arietis	+4	+4	−17	+1	+16	+9	+23	−9	+24
α Ceti	−8	−21	+2	+4	−2	+5	−8	+15	+19
α Tauri	−12	+2	−11	−19	−10	−7	−19	−27	+13
α Aurigæ	−6	+2	+2	−48	−55	....	−4	−49	+28
β Orionis	+1	+5	−5	−33	−15	−10	−52	−62	+4
β Tauri	−9	+9	−14	−13	−30	−41	−45	+19	+8
α Orionis	−10	−1	−24	−15	−42	−12	−31	−25	−15
α Canis Majoris	−9	+1	−20	−25	−25	....	−64	−64	....
α Canis Minoris	−9	−25	−10	−17	−42	−11	−47	−61	−13
β Geminorum	−12	−14	−21	−24	−43	−14	−32	−46	−20
α Hydræ	−25	−13	−16	−36	−33	+6	−53	−32	−11
α Leonis	−13	−16	−6	−32	−46	−32	−28	−51	+2
β Leonis	−23	−17	−20	−17	−6	−35	−23	+7	+11
α Virginis	−4	−9	−30	−4	−16	−6	+1	−8	+31
α Bootis	+2	+0	−28	+5	+9	−16	−1	+5	−7
α^2 Libræ	−11	+10	−10	+3	−10	....	+17	+32	−18
α Coronæ	−0	+7	−13	+14	+27	−19	+10	+39	+11
α Serpentis	+5	+8	+1	+2	+18	−6	+8	+29	+4
α Scorpii	−1	+13	+13	−11	+24	....	+27	+14	+33
α Herculis	−13	+4	+30	+13	+31	−14	+61	+30	+12
α Ophiuchi	−6	+20	+8	+16	+37	+8	+43	+33	−1
α Lyræ	+11	+7	+13	+30	+22	+45	+25	+68	−12
γ Aquilæ	+12	+5	+24	+24	+52	+17	+36	+48	−2
α Aquilæ	+2	+12	+21	+30	+49	+19	+29	+43	+35
β Aquilæ	+13	+7	+16	+35	+48	−2	+57	+42	+24
α^2 Capricorni	+3	+29	+21	+17	+18	....	+79	+77	....
α Cygni	+17	+10	+21	+29	+38	+68	+23	−14	−4
α Aquarii	+23	+18	+22	+36	+16	+0	+42	+53	−10
α Piscis Australis	+20	−4	+27	+52	+25	....	+16	+61	−24
α Pegasi	+11	+2	+29	+35	+39	+7	+34	+10	−6
[v]	+136 −178	+196 −120	+320 −245	+379 −294	+508 −375	+206 −238	+570 −406	+654 −448	+278 −145

TABLE VII.

α Andromedæ	−15	+2	+11	−10	−3	+6	+5	−1	+17
γ Pegasi	+1	+5	+17	+2	+1	−29	−9	−7	−4
α Arietis	−2	+2	−28	−5	+15	+1	+24	−5	+24
α Ceti	−11	−20	−3	+6	+6	+3	+3	+30	+20
α Tauri	−10	+7	−6	−5	+13	−1	+8	+5	+15
α Aurigæ	−2	+9	+11	−30	−27	....	+29	−12	+31
β Orionis	+6	+12	+4	−15	+13	−1	−19	−25	+7
β Tauri	−4	+17	−4	+7	−1	−31	−11	+57	+11
α Orionis	−4	+8	−11	+8	−9	−0	+7	+16	−12
α Canis Majoris	+0	+11	−2	+3	+13	....	−21	−19	....
α Canis Minoris	+1	−14	+11	+13	−3	+7	−2	−15	−9
β Geminorum	−1	−3	+1	+7	−4	+4	+12	+0	−16
α Hydræ	−13	−2	+9	−5	+5	+26	−11	+10	−7
α Leonis	+1	−5	+19	−2	−11	−12	+10	−13	+6
β Leonis	−11	−9	+3	+6	+18	−18	+3	+29	+13
α Virginis	+4	−5	−15	+8	−7	+5	+9	−4	+32
α Bootis	+7	+1	−18	+10	+9	−9	−3	−2	−7
α^2 Libræ	−8	+9	−3	+3	−16	....	+9	+18	−18
α Coronæ	+1	+4	−11	+8	+13	−19	−8	+18	+10
α Serpentis	+5	+5	+2	−5	+2	−8	−11	+6	+3
α Scorpii	−2	+8	+9	−24	+2	....	+1	−16	+31
α Herculis	−18	−3	+21	−5	+3	−23	+26	−7	+9
α Ophiuchi	−11	+12	−3	−5	+6	−3	+7	−6	−4
α Lyræ	+2	−3	−4	+3	−15	+30	−17	+23	−15
Aquilæ	+1	−6	+2	−7	+12	−2	−8	+2	−6
α Aquilæ	−9	+1	−1	−1	+9	+0	−16	−3	+31
β Aquilæ	+2	−4	−7	+4	+8	−21	+12	−4	+20
α^2 Capricorni	−9	+17	−2	−14	−22	....	+34	+32	....
α Cygni	+5	−1	−3	−3	−2	+48	−21	−59	−7
α Aquarii	+10	+7	−3	+6	−19	−20	+4	+16	−13
α Piscis Australis	+8	−14	+3	+25	−5	....	−17	+30	−27
α Pegasi	−2	−7	+5	+9	+10	−12	+3	−19	−9
[v]	+54 −132	+137 −96	+127 −124	+128 −136	+158 −144	+130 −209	+208 −174	+292 −217	+280 −154

TABLE VIII.

	Green-wich.	Wash'g-ton, I.	Oxford.	Paris.	Mel-bourne.	Edin-burgh.	Bruss'ls.	Wash'g-ton, II.	Harv'd College.
α Andromedæ	−12	+1	+10	−9	−4	+5	+2	−1	+11
γ Pegasi	+4	+4	+17	+2	+0	−25	−11	−9	−9
α Arietis	+1	+1	−29	−4	+14	+2	+21	−5	+18
α Ceti	−9	−21	−3	+5	+5	+9	+2	+27	+16
α Tauri	−7	+6	−7	−5	+12	+2	+6	+3	+10
α Aurigæ	+1	+8	+10	−27	−27	....	+25	−9	+25
β Orionis	+8	+11	+4	−17	+12	+8	−19	−30	+4
β Tauri	−1	+16	−5	+8	−2	−32	−14	+57	+5
α Orionis	−2	+7	−11	+8	−10	+5	+5	+13	−17
α Canis Majoris	+0	+10	−2	+1	+12	....	−21	−26	....
α Canis Minoris	+3	−15	+11	+12	−4	+13	−3	−18	−13
β Geminorum	+2	−4	+0	+8	−5	+3	+9	+0	−22
α Hydræ	−11	−3	+9	−7	+4	+35	−9	+5	−10
α Leonis	+4	−6	+19	−2	−12	−8	+8	−15	+1
β Leonis	−8	−10	+1	+5	+17	−15	+1	+27	+8
α Virginis	+5	−6	−15	+6	−8	+14	+9	−10	+29
α Bootis	+10	+0	−19	+11	+8	−7	−5	−3	−12
α² Libræ	−7	+8	−3	+1	−17	....	+9	+12	−21
α Coronæ	+4	+3	−12	+9	+12	−19	−11	+18	+4
α Serpentis	+7	+4	+2	−5	+1	−3	−12	+3	−1
α Scorpii	−1	+7	+9	−27	+1	....	+2	−24	+29
α Herculis	−15	−4	+21	−5	+2	−19	+26	−9	+4
α Ophiuchi	−8	+11	−3	−5	+5	+1	+5	−8	−9
α Lyræ	+6	−4	−5	+5	−16	+27	−20	+25	−21
γ Aquilæ	+4	−7	+2	−7	+11	+3	−10	+0	−11
α Aquilæ	−7	+0	−1	−1	+8	+5	−18	−6	+26
β Aquilæ	+4	−5	−7	+4	+7	−16	+11	−7	+16
α² Capricorni	−8	+16	−2	−16	−23	....	+34	+26	....
α Cygni	+8	−2	−4	+0	−2	+43	−25	−56	−13
α Aquarii	+12	+6	−3	+5	−20	−13	+3	+12	−17
α Piscis Australis	+8	−14	+4	+21	−7	....	−16	+21	−28
α Pegasi	+1	−8	+5	+9	+9	−8	+1	−21	−14
[v]	+92 −96	+119 −109	+124 −131	+120 −137	+140 −157	+175 −165	+179 −194	+249 −257	+206 −218

TABLE IX.

α Andromedæ	−13	+6	+10	−14	−5	+7	+1	−2	+13
γ Pegasi	+3	+9	+17	−3	−1	−23	−12	−10	−7
α Arietis	+1	+1	−25	−5	+11	+9	+18	−9	+12
α Ceti	−8	−23	+2	+6	+3	+16	−1	+22	+8
α Tauri	−5	+2	−3	−1	+12	+6	+5	+0	+3
α Aurigæ	+2	+2	+12	−23	−27	....	+25	−10	+19
β Orionis	+9	+5	+6	−12	+12	+9	−19	−31	−2
β Tauri	+0	+10	−3	+13	−2	−31	−14	+56	+0
α Orionis	−1	+2	−10	+13	−9	+4	+6	+13	−20
α Canis Majoris	+1	+6	−4	+6	+14	....	−19	−23	....
α Canis Minoris	+3	−17	+7	+14	−2	+7	+0	−13	−8
β Geminorum	+2	−5	−4	+10	−2	−3	+12	+5	−17
α Hydræ	−12	+0	+4	−9	+6	+28	−6	+10	−2
α Leonis	+2	−2	+15	−5	−11	−13	+10	−12	+9
β Leonis	−9	−5	+0	+0	+16	−14	+0	+27	+11
α Virginis	+5	−3	−12	+3	−10	+20	+7	−14	+26
α Bootis	+11	+0	−15	+10	+6	+0	−8	−7	−18
α² Libræ	−6	+7	+2	+1	−19	....	+6	+7	−29
α Coronæ	+5	+0	−7	+11	+10	−13	−14	+13	−4
α Serpentis	+8	+0	+7	−2	−1	+3	−15	−2	−10
α Scorpii	+1	+2	+13	−23	+0	....	+1	−27	+22
α Herculis	−14	−10	+23	−1	+2	−18	+26	−10	−2
α Ophiuchi	−7	+5	−2	+0	+5	+1	+5	−8	−13
α Lyræ	+7	−8	−6	+10	−14	+23	−18	+27	−21
γ Aquilæ	+4	−8	−2	−5	+14	−3	−7	+5	−6
α Aquilæ	−7	−1	−5	+1	+11	−1	−15	−1	+31
β Aquilæ	+4	−6	−11	+6	+10	−23	+14	−2	+21
α² Capricorni	−9	+16	−7	−15	−21	....	+37	+31	....
α Cygni	+7	−1	−9	+0	+0	+36	−22	−51	−5
α Aquarii	+11	+10	−8	+2	−18	−18	+5	+16	−8
α Piscis Australis	+6	−9	+1	+16	−7	....	−15	+23	−21
α Pegasi	−1	−3	+3	+3	+9	−10	+2	−19	−8
[v]	+92 −92	+83 −101	+122 −133	+125 −118	+141 −149	+169 −170	+180 −185	+255 −251	+175 −201

SYSTEM OF WEIGHTS.

	[vv]	w'	w''	w
For Greenwich	1482	10.0	10.0	10
Washington, I.	1962	7.3	8.8	8
Oxford	3201	4.5	9.2	7
Paris	3187	4.6	8.8	6
Melbourne	4010	3.5	7.2	5
Edinburgh	8493	1.7	8.9	5
Brussels	6527	2.2	8.8	5
Washington, II.	13858	1.1	5.6	3
Harvard College	7802	2.0	8.0	2

With the weights w we have finally:—

TABLE X.

	Assumed correction to Newcomb.	Derived correction to assumed R. A.	Final correction to Newcomb.
α Andromedæ	−3	+1	−2
γ Pegasi	−6	+0	−6
α Arietis	−3	+0	−3
α Ceti	−3	+1	−2
α Tauri	+1	−1	+0
α Aurigæ	−21	+0	−21
β Orionis.	+18	+0	+18
β Tauri	+6	−2	+4
α Orionis.	+6	+0	+6
α Canis Majoris	+7	+1	+8
α Canis Minoris	+6	+0	+6
β Geminorum	−2	−1	−3
α Hydræ	−2	+0	−2
α Leonis	−3	+0	−3
β Leonis	−3	+0	−3
α Virginis	−2	−1	−3
α Bootis	+4	+0	+4
α^2 Libræ	+6	+2	+8
α Coronæ	−2	+0	−2
α Serpentis	+4	+0	+4
α Scorpii	+0	+1	+1
α Herculis	−2	+1	−1
α Ophiuchi	+4	+1	+5
α Lyræ	−7	−1	−8
γ Aquilæ	+1	+1	+2
α Aquilæ	−3	+1	−2
β Aquilæ	+4	+0	+4
α^2 Capricorni	+1	−2	−1
α Cygni	−14	+2	−12
α Aquarii	+5	−1	+4
α Piscis Australis	+11	+0	+11
α Pegasi	+0	+1	+1
[v]	+79 −76	+13 −9	+81 −74

In the following table will be found the predicted seconds of Right Ascension for every five years from 1870 to 1900:—

TABLE XI.

	1870.	1875.	1880.	1885.	1890.	1895.	1900.
	s.	s.	s.	s.	s.	s.	s.
α Andromedæ .	40.321	55.762	11.208	26.659	42.114	57.573	13.033
γ Pegasi	32.626	48.036	3.449	18.864	34.282	49.702	5.125
α Arietis	50.963	7.800	24.648	41.491	58.344	15.208	32.066
α Ceti	29.148	44.792	0.438	16.086	31.737	47.391	3.047
α Tauri	27.785	44.963	2.144	19.327	36.514	53.702	10.894
α Aurigæ	5.305	27.415	49.529	11.647	33.769	55.895	18.024
β Orionis	17.472	31.875	46.280	0.685	15.091	29.498	43.906
β Tauri	4.530	23.469	42.411	1.354	20.300	39.247	58.197
α Orionis	8.056	24.288	40.522	56.756	12.991	29.226	45.463
α Canis Majoris	25.042	38.284	51.551	4.847	18.178	31.401	44.504
α Canis Minoris	29.708	45.400	1.188	16.904	32.678	48.414	4.113
β Geminorum .	21.484	39.891	58.295	16.696	35.094	53.488	11.879
α Hydræ	11.988	26.685	41.431	56.177	10.928	25.668	40.414
α Leonis	26.795	42.807	58.815	14.822	30.826	46.827	2.826
β Leonis	25.684	40.960	56.285	11.607	26.928	42.247	57.564
α Virginis . . .	20.811	36.570	52.331	8.096	23.863	39.634	55.407
α Bootis	48.964	57.687	11.310	24.984	38.658	52.333	6.009
α² Libræ	41.409	57.948	14.482	31.024	47.570	4.121	20.675
α Coronæ	11.072	23.766	36.461	49.157	1.853	14.550	27.247
α Serpentis . . .	51.970	6.728	21.477	36.233	50.991	5.750	20.510
α Scorpii	26.392	44.731	3.078	21.418	39.768	58.121	16.478
α Herculis . . .	43.241	56.905	10.571	24.237	37.904	51.572	5.241
α Ophiuchi . . .	54.054	7.965	21.877	35.790	49.704	3.619	17.535
α Lyræ	32.238	42.389	52.545	2.701	12.857	23.014	33.171
γ Aquilæ	4.765	19.027	33.289	47.550	1.812	16.073	30.333
α Aquilæ	26.428	41.068	55.708	10.347	24.985	39.623	54.260
β Aquilæ	55.662	10.398	25.135	39.870	54.606	9.341	24.076
α² Capricorni . .	50.420	7.089	23.755	40.419	57.081	13.741	30.399
α Cygni	0.044	10.264	20.484	30.705	40.927	51.149	1.371
α Aquarii	6.389	21.806	37.222	52.637	8.052	23.465	38.877
α Piscis Australis	27.756	44.398	1.035	17.667	34.298	50.914	7.529
α Pegasi	17.207	32.127	47.049	1.972	16.896	31.822	46.749

In Tables XII., XIII., and XIV. will be found the corrections necessary to reduce the observations made at different observatories to a homogeneous system.

Let

C = the correction to be applied to the observations.

Then

$$C = \varepsilon + (m \sin \alpha + n \cos \alpha) + (m' \sin 2\,\alpha + n' \cos 2\,\alpha) + (a \sin \delta + b \cos \delta).$$

Thus for Edinburgh, when $\alpha = 6^h$ and $\delta = -20^\circ$: —

$$C = \overset{s.}{+.036} \quad \overset{s.}{-.013} \quad \overset{s.}{+.002} \quad \overset{s.}{+.046} = \overset{s.}{+.071}.$$

TABLE XII.

Tabular Corrections for Errors of Single Period.

R. A.	Greenwich.	Washington, I.	Oxford.	Paris.	Melbourne.	Edinburgh.	Brussels.	Washington, II.	Harvard College.
h.	s.	s.	s.	s.	s.	s.	s.	s.	s.
0	+.011	+.007	+.021	+.021	+.021	+.016	+.022	+.019	+.002
1	+.009	+.005	+.016	+.014	+.011	+.013	+.011	+.007	+.001
2	+.006	+.002	+.011	+.006	+.001	+.008	+.000	—.005	+.001
3	+.003	—.001	+.005	—.002	—.009	+.002	—.012	—.017	—.001
4	+.000	—.004	—.002	—.011	—.020	—.003	—.023	—.028	—.002
5	—.004	—.007	—.009	—.018	—.028	—.009	—.032	—.036	—.002
6	—.007	—.009	—.014	—.024	—.034	—.013	—.039	—.042	—.003
7	—.010	—.011	—.019	—.028	—.038	—.017	—.044	—.046	—.004
8	—.012	—.012	—.022	—.031	—.040	—.019	—.045	—.046	—.004
9	—.013	—.011	—.025	—.032	—.039	—.020	—.044	—.043	—.003
10	—.013	—.010	—.025	—.030	—.035	—.020	—.038	—.037	—.003
11	—.013	—.009	—.024	—.026	—.029	—.019	—.031	—.029	—.003
12	—.011	—.007	—.021	—.021	—.021	—.016	—.022	—.019	—.002
13	—.009	—.005	—.016	—.014	—.011	—.013	—.011	—.007	—.001
14	—.006	—.002	—.011	—.006	—.001	—.008	+.000	+.005	—.001
15	—.003	+.001	—.005	+.002	+.009	—.002	+.012	+.017	+.001
16	—.000	+.004	+.002	+.011	+.020	+.003	+.023	+.028	+.002
17	+.004	+.007	+.009	+.018	+.028	+.009	+.032	+.036	+.002
18	+.007	+.009	+.014	+.024	+.034	+.013	+.039	+.042	+.003
19	+.010	+.011	+.019	+.028	+.038	+.017	+.044	+.046	+.004
20	+.012	+.012	+.022	+.031	+.040	+.019	+.045	+.046	+.004
21	+.013	+.011	+.025	+.032	+.039	+.020	+.044	+.043	+.003
22	+.013	+.010	+.025	+.030	+.035	+.020	+.038	+.037	+.003
23	+.013	+.009	+.024	+.026	+.029	+.019	+.031	+.029	+.003

TABLE XIII.

Tabular Corrections for Errors of Double Period.

R. A.	Green-wich.	Washing-ton, I.	Oxford.	Paris.	Mel-bourne.	Edin-burgh.	Brussels.	Washing-ton, II.	Harvard College.
h.	s.	s.	s.	s.	s.	s.	s.	s.	s.
0	+.001	—.005	+.000	+.005	+.001	—.002	+.001	+.001	—.002
1	+.000	—.003	—.002	+.003	+.002	—.005	+.003	+.003	+.002
2	+.000	+.000	—.004	+.001	+.003	—.007	+.004	+.005	+.006
3	—.001	+.002	—.005	—.001	+.002	—.007	+.003	+.005	+.008
4	—.002	+.004	—.004	—.003	+.001	—.005	+.002	+.003	+.008
5	—.002	+.005	—.002	—.005	+.000	—.001	+.001	+.001	+.006
6	—.001	+.005	—.000	—.005	—.001	+.002	—.001	—.001	+.002
7	+.000	+.003	+.002	—.003	—.002	+.005	—.003	—.003	—.002
8	+.000	+.000	+.004	—.001	—.003	+.007	—.004	—.005	—.006
9	+.001	—.002	+.005	+.001	—.002	+.007	—.003	—.005	—.008
10	+.002	—.004	+.004	+.003	—.001	+.005	—.002	—.003	—.008
11	+.002	—.005	+.002	+.005	+.000	+.001	—.001	—.001	—.006
12	+.001	—.005	+.000	+.005	+.001	—.002	+.001	+.001	—.002
13	+.000	—.003	—.002	+.003	+.002	—.005	+.003	+.003	+.002
14	+.000	+.000	—.004	+.002	+.003	—.007	+.004	+.005	+.006
15	+.001	+.002	—.005	+.001	+.002	—.007	+.003	+.005	+.008
16	—.002	+.004	—.004	—.003	+.001	—.005	+.002	+.003	+.008
17	—.002	+.005	—.002	—.005	+.000	—.001	+.001	—.001	+.006
18	—.001	+.005	+.000	—.005	—.001	+.002	—.001	—.001	+.002
19	+.000	+.003	+.002	—.003	—.002	+.005	—.003	—.003	—.002
20	+.000	+.000	+.004	—.001	—.003	+.007	—.004	—.005	—.006
21	+.001	—.002	+.005	+.001	—.002	+.007	—.003	—.005	—.008
22	+.002	—.004	+.004	+.003	—.001	+.005	—.002	—.003	—.008
23	+.002	—.005	+.002	+.005	+.000	+.001	—.001	—.001	—.006

TABLE XIV.

Tabular Corrections depending on the Declination.

δ	s.	s.	s.	s.	s.	s.	s.	s.	s.
—30°	+.015	—.012	—.009	—.024	—.009	+.059	—.002	—.033	—.033
—20	+.011	—.009	—.008	—.019	—.008	+.046	—.002	—.027	—.025
—10	+.007	—.007	—.006	—.014	—.007	+.033	—.003	—.020	—.018
+ 0	+.003	—.004	—.004	—.008	—.005	+.018	—.003	—.012	—.010
+10	—.001	—.001	—.002	—.002	—.003	+.003	—.003	—.004	—.002
+20	—.005	+.001	+.000	+.003	—.001	—.012	—.003	+.005	+.007
+30	—.009	+.004	+.001	+.010	+.001	—.027	—.004	+.013	+.015
+40	—.013	+.007	+.004	+.016	+.003	—.042	—.003	+.021	+.023
+50	—.016	+.009	+.006	+.021	+.005	—.055	—.003	+.028	+.031
+60	—.020	+.011	+.008	+.025	+.006	—.067	—.002	+.034	+.037
+70	—.022	+.013	+.009	+.029	+.007	—.076	—.002	+.040	+.042
+80	—.023	+.015	+.010	+.032	+.009	—.083	—.002	+.045	+.046
+90	—.024	+.016	+.011	+.034	+.010	—.087	—.001	+.047	+.048

PART II.

IN seeking for an explanation of the origin of periodic errors in observed Right Ascensions, the following facts, drawn from the preceding discussion, will not escape attention: —

I. That for the observatories under consideration, the coefficients of sin a, and also of cos a, have the same sign, varying only in magnitude.

II. That for each observatory the maximum of negative errors occurs at about 6 hours of Right Ascension, the maximum of positive errors at about 18 hours, the zero of error varying but little from 8 hours.

III. That the periodic error depending on the Declination, is zero at about 12° north.

There seems to be only one circumstance that can vitiate these conclusions, viz., that the derived standard catalogue is itself subject to the errors in question. In order to remove doubt on this point as far as possible, I give in Tables I. and II. a comparison of the standard Right Ascensions with the following authorities, viz.: Maskelyne, from 1765 to 1807; Struve, 1825; Struve, 1830; Argelander, 1830; Pulkowa, 1845; and Newcomb, 1870. These authorities are selected because there is good reason to suppose that the observations are in a great measure free from errors of single period. Certainly no more severe test than this can well be applied; for the standard catalogue has been formed quite independently of them. If it is found that the Right Ascensions derived from this discussion of only modern observations, satisfy observations distributed over a range of nearly 100 years, they must be accepted as quite near the truth. If the comparison indicates no periodic errors of greater magnitude than the probable errors of observation, then the standard catalogue must also be regarded as quite nearly free from these errors.

Instead of using the various catalogues constructed from Maskelyne's observations, I give in Table I., in hundredths of seconds, the comparison for each year, the data being derived from the Ledger of Stars, prepared with great care by the Rev. Robert Main. The final Right Ascensions given by Mr. Main are corrected for quite a large number of errors found in Maskelyne's original computations. This direct comparison will also enable us to form an estimate of the relative value of the individual observations. Argelander's places of a Canis Majoris and a Canis Minoris have been corrected by $+.04^s$ and $-.04^s$ respectively, on account of change of position between 1826 and 1830. Struve's positions for 1830 have been corrected by $+.05^s$ and $-.05^s$ respectively. From the direct residuals have been subtracted the values of r'' derived from the following equations: —

Struve	1825,	$r'' = +.036^s \sin\delta$	$-.007^s \cos\delta.$
Struve	1830,	$= +.074 \sin\delta$	$-.015 \cos\delta.$
Argelander	1830,	$= -.028 \sin\delta$	$+.005 \cos\delta.$
Pulkowa	1845,	$= -.023 \sin\delta$	$+.004 \cos\delta.$
Newcomb	1870,	$= +.014 \sin\delta$	$-.002 \cos\delta.$

TABLE I. — Comparison with Maskelyne's Observations.

Year . . .	1765[1].	1765[2].	1766	1767.	1768.	1769.	1770.	1771.	1772.
ε . . .	+.33.	+.07.	+.29.	+.04.	+.12.	+.00.	+.09.	+.03	+.03.
α Andromedæ . .	−15	−16	−3	−1	−3	−3	−7	+3	−22
γ Pegasi	−13	−15	−3	+4	−4	−6	−6	−2	−11
α Arietis	−8	+0	−5	−4	−13	−5	−11	+4	−6
α Ceti	−15	+9	−7	+12	−10	−1	−10	. . . .	. . . .
α Tauri	−3	+2	−7	+3	+8	+0	+4	−7	+3
α Aurigæ. . . .	+26	+19	. . . .	. . . .	. . . .	. . . .	. . . .	. . . .	. . . .
β Orionis	−15	−11	+(20)	+13	+5	−8	−3	−3	+6
β Tauri	+11	+4	. . . .	−4	. . . .	−(36)	−5	. . . .	. . . .
ε Orionis	+3	+2	+4	+0	+10	−3	+6	+2	−4
α Canis Majoris .	+12	+8	−5	+5	+(52)	−(49)	. . . .	. . . .	. . . .
α Canis Minoris .	−4	−11	−2	−1	+1	−5	−6	−4	+5
β Geminorum . .	+4	+2	+17	+1	+7	+8	+5	+7	+3
α Hydræ	−13	−13	−8	−13	−14	−7	−18	. . . .	. . . .
α Leonis	+6	+0	+7	+2	+9	+12	−2	+2	+0
β Leonis	+18	+14	−4	−2	+1	−3	+6	−9	+22
α Virginis . . .	+16	+28	+4	+7	+8	−1	+16	+17	+11
α Bootis	+4	+1	+5	−7	−7	+1	+2	+1	−4
α[2] Libræ	+18	+17	+2	−15	+18	+(16)	+26	. . . .	. . . .
α Coronæ. . . .	+0	+12	+7	−12	+11	−6	+8	−1	−3
α Serpentis . . .	+3	+11	+6	−6	+2	+3	+4	+2	+4
α Scorpii	−6	+0	−9	−13	+12	−2	−6	−7	−1
α Herculis . . .	+42	+5	+(41)	. . . .	+(35)	. . . .	. . . .	. . . .	. . . .
α Ophiuchi . . .	−2	−5	−5	−1	−8	+2	+0	+1	−4
α Lyræ	−4	−3	−20	+6	+(25)	. . . .	+(21)	. . . .	. . . .
γ Aquilæ. . . .	−3	+1	+5	+4	−5	+13	+9	. . . .	. . . .
α Aquilæ. . . .	−8	−5	−1	−1	−9	+3	−6	+0	+0
β Aquilæ. . . .	−8	−2	−1	−1	+2	+4	+7	. . . .	. . . .
α[2] Capricorni . .	−3	−19	+0	+9	−4	+3	+3	+3	+4
α Cygni	−11	−12	+9	+1	+6	. . . .	−5	. . . .	. . . .
α Aquarii . . .	−1	−1	−2	−5	−4	+2	−1	−5	+0
α Piscis Australis	−6	+2	+3	+15	+(26)	. . . .	. . . .	. . . .	. . . .
α Pegasi	−27	−26	−1	+7	−10	+4	−1	−2	−10
[v]	+1.63 −1.65	+1.37 −1.39	+.69 −.83	+.89 −.86	+1.00 −.91	+.55 −.50	+.96 −.87	+.42 −.40	+.58 −.65

TABLE I. (*continued*).

Year . . .	1779.	1780.	1781.	1782.	1783.	1784.	1785.	1796.	1797.
ε . . .	+.03.	+.02.	−.02.	+.03.	+.00.	+.01.	+.00.	+.32.	+.34.
α Andromedæ . .	+7	+0	−6	−8	−4	−8	−2	+1	+6
γ Pegasi	−1	−6	−1	−4	−7	−4	−4	+0	+5
α Arietis	−4	+8	+9	−1	−10	−4	+2	+2	+5
α Ceti	−8	+3	+12	+1	−3	+2	−5	+10	+3
α Tauri	+4	+3	−9	−2	−7	−6	+2	+4	+7
α Aurigæ. . . .	. . . .	. . . .	+7	−18	−11	+8	+4	+4	−2
β Orionis	−3	−2	−3	+1	+0	+1	+3	−9	+0
β Tauri	+11	+5	+2	−7	−4	−3	−8	+3	+2
α Orionis	+8	−8	−2	+1	−4	−1	+0	−2	+5
α Canis Majoris .	+(17)	−3	−(23)	−8	−1	+1	+1	−11	+3
α Canis Minoris .	−(17)	+3	−7	+5	+4	+1	+4	+9	+3
β Geminorum . .	. . . .	−2	−10	−(63)	−2	−3	−2	+15	−1
α Hydræ	−(27)	−(19)	−7	+4	+0	−6	+3	−8	−8
α Leonis	−3	−2	+10	+3	−4	+5	+12	−6	+1
β Leonis	+4	+14	+3	+5	+1	+18	+2	−8	−7
α Virginis . . .	−14	+5	−3	+8	+8	−3	+2	−8	−4
α Bootis	+11	−4	−10	+0	+4	−6	−5	−4	−2
α[2] Libræ	−13	−7	−5	+5	+15	+2	+2	+1	−14
α Coronæ . . .	+3	−8	−8	+2	+1	−4	−8	+0	−9
α Serpentis . . .	−6	−6	−8	+5	+2	+3	−4	−3	−4
α Scorpii	. . . .	+1	−6	−6	−1	+5	+1	−18	−13
α Herculis . . .	+7	−8	. . . .	−2	+5	+0	−8	−1	+1
α Ophiuchi . . .	−8	−7	+4	−1	+3	−1	+2	+1	−3
α Lyræ	+19	−3	−4	−2	−6	−3	−3	+5	+0
γ Aquilæ. . . .	+9	+4	+13	+7	+10	+10	+10	+11	+5
α Aquilæ. . . .	+0	+0	+4	−1	+2	+1	+2	+4	+3
β Aquilæ. . . .	−5	−5	+2	−1	+1	+0	−5	+3	+0
α[2] Capricorni . .	−13	−5	+4	−3	+4	+6	+2	−6	−5
α Cygni	+19	. . . .	+9	−4	+1	−10	+2	+6	+1
α Aquarii . . .	−18	+2	+3	+5	+4	+5	−4	+6	+6
α Piscis Australis	−19	+23	+15	+11	+3	+(19)	+6	−9	−1
α Pegasi	+2	−7	+1	+4	−1	+3	+0	+0	+8
[v]	+1.04 −1.15	+.71 −.83	+.98 −.89	+.67 −.68	+.68 +.65	+.71 −.62	+.62 −.58	+.85 −.93	+.64 −.73

TABLE I. (*continued*).

Year	1798.	1799.	1800.	1801.	1804.	1805.	1806.	1807.
ε	+.39.	+.36.	+.37.	+.34.	+.13.	+.18.	+.14.	+.16.
α Andromedæ	+ 6	+ 8	+ 5	+ 0	− 11	+ 2	+ 1	+ 1
γ Pegasi	+ 9	+ 4	+ 5	+ 5	− 1	+ 1	+ 3	+ 2
α Arietis	+ 12	+ 2	+ 10	− 1	− 6	+ 5	− 5	+ 1
α Ceti	+ 6	+ 10	+ 7	− 1	+ 7	+ 3	+ 9	+ 11
α Tauri	− 5	− 9	+ 5	− 7	−(14)	+ 2	+ 18	− 6
α Aurigæ	− 8	− 15	+ 10	− 27	− 20	− 4	+ 3	+ 1
β Orionis	+ 3	− 14	− 3	− 16	+ 11	+ 7	+ 9	+ 1
β Tauri	− 2	− 6	+ 4	− 14	+ 9	− 3	− 4	− 10
α Orionis	+ 3	− 13	− 4	− 14	−(20)	+ 4	− 4	− 1
α Canis Majoris	− 5	− 1	− 10	− 12	+ 3	+ 7	− 7	+ 3
α Canis Minoris	+ 9	− 3	− 6	+ 7	+ 5	+ 0	− 6	− 6
β Geminorum	+ 4	+ 3	− 1	+ 4	− 5	− 2	− 10	− 8
α Hydræ	− 4	− 9	− 17	− 12	+(13)	− 4	−(19)	. . . .
α Leonis	− 3	− 2	− 18	+ 13	+(15)	− 1	+(15)	+ 8
β Leonis	− 3	+ 8	+ 1	+ 23	+ 1	− 11	− 10	+ 0
α Virginis	− 8	− 5	+ 3	+ 9	+ 11	−(28)	− 6	+ 5
α Bootis	− 1	+ 8	+ 3	+ 14	− 12	− 1	− 4	−(17)
α^2 Libræ	. . . .	−(28)	. . . .	+(29)	. . . .	. . . .	. . . .	− 1
α Coronæ	− 5	+ 10	+ 2	− 3	− 10	+ 0	− 2	− 7
α Serpentis	− 2	+ 0	+ 0	+ 3	+ 3	+ 0	+ 11	− 3
α Scorpii	− 18	− 9	− 18	+ 1	+ 7	+(22)	. . . .	+ 7
α Herculis	− 4	− 1	+ 4	− 8	− 8	+ 0	+ 1	− 5
α Ophiuchi	− 1	− 2	+ 2	+ 4	− 4	+ 2	+ 10	− 3
α Lyræ	− 1	+ 7	+ 5	+ 7	− 2	− 9	− 9	− 3
γ Aquilæ	+ 2	+ 14	+ 13	+ 21	− 1	− 2	+ 3	+ 3
α Aquilæ	− 2	+ 2	+ 3	+ 7	+ 3	− 2	+ 3	+ 2
β Aquilæ	− 3	+ 0	+ 1	+ 7	+ 2	− 1	+ 3	− 1
α^2 Capricorni	− 5	− 7	− 7	− 5	+ 2	+ 0	− 3	− 4
α Cygni	− 4	+ 0	+ 9	− 14	+ 18	− 6	− 8	− 2
α Aquarii	+ 2	+ 5	+ 4	+ 3	+ 9	+ 3	+ 4	− 1
α Piscis Australis	+ 3	− 2	− 9	− 11	+(21)	+ 4	+ 4	+ 9
α Pegasi	+ 13	+ 10	+ 10	+ 5	− 5	+ 4	+ 2	+ 5
[v]	+.72 −.84	+.91 −.98	+1.06 − .93	+1 33 −1.45	+ 91 −.85	+.44 −.46	+.84 −.78	+.62 −.61

TABLE II.

	Maskelyne. 1765–1772.	Maskelyne. 1779–1785.	Maskelyne. 1796–1807.	Struve 1825.	Struve 1830.	Argelander. 1830.	Pulkowa. 1845.	Newcomb. 1870.	Mean.
α Andromedæ	− 74	− 30	+ 19	+ 51	+ 45	− 10	+ 4	− 6	+ 17
γ Pegasi	− 62	− 39	+ 33	− 9	− 38	− 26	− 4	− 6	− 17
α Arietis	− 53	+ 0	+ 25	− 18	− 29	− 2	− 17	− 8	− 15
α Ceti	− 31	+ 3	+ 65	− 1	− 4	− 1	− 6	− 17	− 6
α Tauri	+ 3	− 21	+ 10	+ 24	+ 18	+ 5	+ 26	− 1	+ 14
α Aurigæ	+(225)	− 20	− 58	− 18	+ 13	+ 18	− 1	+ 18	+ 6
β Orionis	− 20	− 4	− 11	− 33	− 19	+ 23	− 3	+ 17	− 3
β Tauri	+ 15	− 6	− 21	+ 22	+ 8	+ 0	+ 7	+ 24	+ 12
α Orionis	+ 22	− 9	− 29	+ 20	+ 20	− 9	+ 20	+ 6	+ 11
α Canis Majoris	+ 50	− 20	− 30	+ 12	+ 20	+ 9	+ 14	− 4	+ 10
α Canis Minoris	− 30	+ 17	+ 12	+ 5	− 3	+ 20	− 20	+ 8	+ 2
β Geminorum	+ 60	− 38	− 1	+ 8	+ 2	+ 0	− 2	+ 1	+ 2
α Hydræ	−123	− 12	− 89	− 17	+ 0	− 17	− 16	+ 8	− 8
α Leonis	+ 40	+ 30	− 10	+ 4	+ 4	+ 3	+ 2	− 4	+ 2
β Leonis	+ 48	+ 67	− 6	− 4	− 11	− 5	− 10	− 6	− 7
α Virginis	+118	+ 4	− 3	+ 18	+ 23	− 8	− 28	− 14	− 2
α Bootis	− 4	− 14	+ 1	+ 7	+ 3	+ 7	− 4	+ 8	+ 4
α^2 Libræ	+110	− 1	− 47	+ 44	+ 48	+ 0	+ 16	+ 21	+ 26
α Coronæ	+ 18	− 31	− 24	− 40	− 36	− 9	+ 8	+ 6	− 14
α Serpentis	+ 32	− 20	+ 5	− 33	− 39	− 10	+ 6	+ 6	− 14
α Scorpii	− 36	− 10	− 74	− 3	+ 1	+ 15	− 2	− 9	+ 0
α Herculis	+ 50	− 10	− 21	− 39	− 38	− 16	+ 23	− 1	− 14
α Ophiuchi	− 24	− 11	+ 6	− 31	− 16	− 7	+ 30	+ 6	− 4
α Lyræ	− 52	− 3	+ 0	+ 19	+ 21	+ 5	− 16	− 15	+ 3
γ Aquilæ	+ 34	+ 90	+ 69	− 9	− 23	− 8	− 6	− 6	− 10
α Aquilæ	− 30	+ 11	+ 23	+ 5	− 1	− 9	− 10	− 10	− 5
β Aquilæ	+ 1	− 19	+ 11	+ 2	+ 3	+ 0	+ 4	+ 6	+ 3
α^2 Capricorni	− 4	− 7	− 40	− 22	− 13	+ 11	− 13	+ 7	− 6
α Cygni	− 20	+ 28	+ 0	+ 3	+ 33	+ 19	− 20	− 13	+ 4
α Aquarii	− 18	− 4	+ 41	+ 10	+ 11	+ 16	+ 0	− 8	+ 6
α Piscis Australis	+ 35	+ 43	− 13	. . . .	. . . .	. . . .	. . . .	− 8	− 8
α Pegasi	− 73	+ 3	+ 55	+ 26	+ 22	− 6	+ 15	− 12	+ 9
[v]	+636 +654	+296 −329	+375 −472	+280 −277	+295 −270	+151 −143	+175 −178	+142 −148	+131 −133

It is apparent from the residuals of Table II. that the standard catalogue, depending wholly on modern observations, is for the most part free both from accidental and periodic errors.

We must therefore conclude, *that if the periodicity is inherent in the observations themselves, it must be produced by a cause common to all instruments and all observers.* It would be difficult to assign any physical cause for the fact, that the zero point of errors depending on the Right Ascension varies but little from 3^h, and on the Declination but little from $+12°$, for all observers and all instruments. No explanation of this periodicity is sufficient which does not account for these observed facts. It is a less violent supposition that the errors in question have been *entirely* transferred from the provisional Right Ascensions on which the clock errors depend. Professor Newcomb has shown, theoretically, that the errors of single period are eliminated in successive revisions by about 1-5th of their entire amount. The errors are simply differently distributed by applying to the standard catalogue the corrections given by observations, but without changing the zero points. I shall now attempt to show why they can never be wholly eliminated by the present method of observation. I begin by comparing with the standard catalogue, the provisional catalogues on which the clock errors depend, for the observatories under consideration. Greenwich, Oxford, and Edinburgh, employ the same star places for clock errors, the places being communicated each year from Greenwich to Oxford and Edinburgh. The Paris observations depend on Leverrier's places of the fundamental stars, together with a large number of additional stars whose places are given by the observations themselves. Washington II. depends wholly on the places of the British Nautical Almanac for 1860. Brussels depends also mainly on the Nautical Almanac. Melbourne depends on the same authority, plus corrections given by the Melbourne observations. Washington I., from 1862 to 1867, depends on the places of the American Ephemeris. From 1867 to 1869, the clock errors depend on the same authority, plus corrections given by the observations from 1862 to 1865. For 1870 they depend on Newcomb's catalogue, found in the volume for 1867. Harvard College depends on the "Pulkowa Hauptsterne." The residuals are given in the following table:—

TABLE III.

	Greenw. Oxford, Edinb.	Leverrier.	Amer. Ephem.	Amer. Ephem. + Wash. Corr.	Newcomb.	Melbourne.	Brussels.	Naut. Alm'nac	Pulkowa.
Year . . .	1865.	1860.	1867.	1867.	1870.	1865.	1865.	1865.	1871.
ε . . .	+ 19	+ 39	+ 14	+ 13	− 22	+ 53	+ 62	+ 67	+ 18
α Andromedæ . .	− 9	+ 1	+ 16	+ 17	− 1	+ 6	+ 14	+ 9	+ 14
γ Pegasi	+ 1	+ 5	− 4	+ 17	− 5	+ 18	+ 12	+ 7	− 4
α Arietis	+ 11	− 19	− 4	− 13	− 5	+ 9	− 17	− 22	+ 3
α Ceti	+ 21	+ 27	− 4	− 23	− 18	+ 13	+ 41	+ 36	+ 9
α Tauri	− 9	− 54	− 14	− 13	+ 1	− 21	− 61	− 65	− 8
α Aurigæ	. . . .	− 37	− 44	. . . .	+ 27	. . . .	− 94	− 99	− 51
β Orionis	+ 21	+ 0	+ 6	− 3	+ 13	− 25	− 84	− 9	− 15
β Tauri	− 39	− 17	+ 6	+ 17	+ 29	− 39	− 51	− 26	− 4
α Orionis	− 19	− 14	− 24	− 23	+ 6	− 26	− 35	− 40	− 13
α Canis Majoris .	. . . .	−(191)	− (94)	− 23	− 10	− 62	− (94)	−(165)	. . . .
α Canis Minoris .	− 49	+ (39)	−(104)	− 83	+ 7	− 67	−(299)	− 1	− 3
β Geminorum . .	− 39	− 26	− 34	− 33	+ 6	− 56	− 45	− 50	− 6
α Hydræ	− 9	+ 7	− 34	− 33	+ 4	− 28	− 47	− 22	− 9
α Leonis	− 29	− 12	− 44	− 33	− 3	− 63	− 45	− 50	+ 1
β Leonis	− 19	− 4	− 24	− 33	− 4	− 36	− 12	− 17	+ 1
α Virginis . . .	+ 11	+ 1	− 34	− 43	− 19	− 4	+ 7	+ 2	. . . .
α Bootis	− 19	+ 11	+ 6	− 3	+ 11	+ 4	+ 2	− 3	+ 21
α² Libræ	+ 11	+ 1	− 4	+ 17	+ 15	+ 17	+ 8	+ 3	. . . .
α Coronæ . . .	− 19	− 8	− 4	− 3	+ 10	+ 6	+ 14	+ 9	+ 9
α Serpentis . . .	+ 11	+ 30	+ 16	+ 17	+ 5	+ 25	+ 13	+ 38	+ 15
α Scorpii	+ 11	− 3	− 34	+ 47	− 17	+ 13	+ 26	− 11	. . . .
α Herculis . . .	− 19	+ 10	+ 16	+ 17	+ 0	+ 18	+ 39	+ 34	− 1
α Ophiuchi . . .	+ 11	+ 8	+ 36	+ 27	+ 7	+ 38	+ 36	+ 31	+ 22
α Lyræ	− 9	− 21	+ 6	+ 7	− 8	+ 59	+ 13	+ 8	− 4
γ Aquilæ	− 9	+ 20	+ 26	. . . .	− 5	+ 50	+ 41	+ 36	− 3
α Aquilæ	+ 11	− 2	+ 26	+ 17	− 10	+ 40	+ 18	+ 13	− 8
β Aquilæ	+ 31	+ 33	+ 36	+ 37	+ 6	+ 55	+ 46	+ 41	+ 8
α² Capricorni . .	+ 31	+ 27	+ 36	+ 37	+ 2	+ 22	+ 55	+ 51	. . . .
α Cygni	. . . .	− 5	+ 16	+ 17	− 4	. . . .	+ 17	+ 12	+ 13
α Aquarii . . .	+ 41	+ 30	+ 16	+ 27	− 10	+ 19	+ 47	+ 42	+ 10
α Piscis Australis	+ 61	+ 88	+ 16	+ 27	− 17	+ 3	+ 51	+ 46	. . . .
α Pegasi	+ 21	− 12	+ 16	+ 7	− 11	+ 28	+ 6	+ 1	− 8
[v]	+305 −296	+249 −234	+296 −306	+352 −362	+149 −147	+443 −427	+506 −491	+419 −415	+126 −137

The following are the values of m and n, computed from the residuals of Table III. For the purpose of easy comparison, the values derived from the observations are repeated:—

	From the Provisional Catalogues.		From the Observations.	
	m.	n.	m.	n.
Greenwich	—17	+21	— 7	+11
Washington, I. . .	—21—28+(5)	+21+21—(7)	— 9	+ 7
Oxford	—17	+21	—14	+21
Paris	—14	+ 3	—24	+21
Melbourne	—41	+26	—34	+21
Edinburgh	—17	+21	—13	+16
Brussels	—47	+19	—39	+22
Washington, II. . .	—38	+18	—42	+19
Harvard College . .	—10	— 2	— 8	+ 2
Means . . .	—25	+17	—21	+16

It therefore appears:—

(*a*) That the periodic errors of the provisional places are largely transferred to the observations.

(*b*) That in general, the coefficients derived from the observations are smaller than those derived from the provisional catalogues, the diminution being quite nearly the amount indicated by theory. But it will be observed that, with the Washington corrections from 1862 to 1865, the periodicity is slightly increased, while in the case of Paris the increase is very decided.

(*c*) That observations made at different observatories, but depending on the same star places, give substantially the same coefficients, the difference being the effect of errors depending on the declination. Thus in the case of Greenwich and Edinburgh, the declination errors tend to neutralize the errors of single period; while in the case of Oxford, the two causes act together, giving larger coefficients.

(*d*) That whether the clock errors depend on the places of the Nautical Almanac directly, as in the case of Washington II., or on the same places corrected by observations, as in the case of Brussels and Melbourne, the periodicity is transferred to the observations with about equal diminution.

It will be observed that the residuals for α Canis Majoris and α Canis Minoris (in parenthesis) have been excluded in the derivation of m and n. Where the erroneous places of these stars enter into the clock errors, as in the case of Washington II., they should be included. In this case two errors are introduced. First, an error through ε, extending over the whole 24 hours. Thus, when ε is negative, all the negative residuals will be too small, and all the positive ones too large. Second, if these residuals are excluded in the formation of ε, but are still included in the derivation of m and n, the effect will be to

increase the value of m relatively to that of n, inasmuch as $\sin a$ is at this point nearly maximum, while $\cos a$ is nearly minimum. Including these stars, the coefficients become as follows:—

Nautical Almanac	$m = -50$	$n = +20$
American Ephemeris . . .	$m = -28$	$n = +26$

Of course the same fundamental catalogue may, through erroneous or irregular proper motions, give different coefficients at different epochs. Thus, for Leverrier, 1870, $m = -23$, and $n = +2$, excluding Sirius and Procyon.

As this tendency to negative residuals in the case of Sirius and Procyon appears in nearly all modern catalogues, it occurred to me that we might find here, an explanation of the way in which periodic errors came to be introduced. I accordingly began the inquiry, whether the errors in question may not be due to the irregular proper motions of the stars employed for determining clock errors, and especially of Sirius and Procyon. An examination of Maskelyne's observations indicates an apparent periodicity in a few cases. This subject, however, is in its detail, reserved for a future communication. It is sufficient for our present purpose to limit the inquiry to Sirius and Procyon. In case these stars were persistently used as clock stars, with places largely in excess of their true positions, all resulting Right Ascensions in their vicinity would be increased in proportion to the number and range of the stars employed. There seems, however, to be several objections to this supposition as a complete explanation.

(1.) The residuals given by various catalogues, at different epochs, do not wholly follow the irregular motions of these stars. Taking Sirius alone and assuming its Right Ascension to be known for 1816 (which I assume to be the time when the present system of differential observations was first introduced), the predicted Right Ascension for each successive year would be too small, and between this date and 1843, the change would amount to $.30^s$. Hence, we should expect a tendency to positive instead of negative residuals between these dates; if Sirius was the sole cause of the disturbances. On the other hand, between 1843 and 1868, the Right Ascension was continually decreasing, hence, if the place given by the first Greenwich Catalogue was carried forward through this interval, the resulting clock errors given by this star were too large. This would of course produce a tendency to the negative residuals which actually exist.

(2.) In the Greenwich system of observations adopted in 1836, and generally followed by all English Observatories, the places of the clock stars have been derived from the observations of the previous year. Hence the periodicity of Sirius and Procyon has since that date been completely allowed for.

(3.) If the irregular motions of these stars were the sole cause of the observed periodic errors of single period, the formula, $r = m \sin a + n \cos a$, would no

longer represent the proper distribution of these errors. As has been remarked, they should be distributed in proportion to their influence on the clock errors. The maximum periodicity should occur at about 7^h and should decrease, slowly at first, and disappear at about 4^h and 10^h. This is what actually happens, as far as the negative residuals are concerned; but it appears from this discussion that the expression, $r = m \sin a + n \cos a$, does, as a matter of fact, represent the proper distribution of the errors of single period over the whole 24 hours. This requires that we shall find at about 18^h, stars giving large positive residuals. As no stars near this hour of Right Ascension appear to have irregular proper motions, the explanation so far fails.

But it appears that the expression, $m \sin a + n \cos a$, is, in a certain sense, the complement of $a \sin \delta + b \cos \delta$. An examination of the several tables will show that when the corrections for errors of single period are applied, there is a constant tendency to negative residuals, but that when the corrections depending on the Declination are applied, the equilibrium is nearly restored. It therefore occurred to me that the supplemental positive residuals required at 18^h may have been introduced by defective or irregular pivots in some of the earlier observations. Inasmuch as all the Maskelyne fundamental stars which have a large south declination (except Sirius) occur between 14^h and 23^h, it is required to find a system of observations, which has been largely adopted as fundamental in differential observations, and in which the coefficients, a and b, are such as will give large positive residuals for low southern stars. As differential observations were first introduced by Pond in 1816, and as his observations have had great weight in the formation of subsequent catalogues, we should naturally expect to find this condition fulfilled in his observations. In order to furnish all the data at present available, in deciding whether the errors in question are in any sense inherent in the observations themselves, or are wholly transferred from the provisional places of the clock stars, I give on the following pages, the residuals, corrected for ε, for all the catalogues at hand, between 1750 and 1871. In a few cases no reduction for equinox has been made, on account of the wide range in the values of the residuals. Such cases are indicated by the omission of ε and $[v]$. Whenever the first and last dates are given, and the mean epoch is *not* given, it is to be understood that the residuals have been derived from all the observations between those dates, as given in the various annual volumes. Provisional authorities are indicated by (F).

TABLE IV.

	Lacaille, 1750.	Bessel's Bradley, 1755.	Maskelyne's Bradley, 1756.	Tobias Mayer, 1756.	Maskelyne, 1766.	Maskelyne, 1770.	Maskelyne, 1784.	Maskelyne, 1790.	Zach, 1800.	Piazzi, 1800.	Lalande, 1800.	D'Agelet, 1800.	D'Agelet (F.) Gould, 1783.	Maskelyne, 1802.	Maskelyne, 1805.	Auwers' Caciatore, 1805.	Leverrier, 1800.	Bessel, 1815.	Pond's Maskelyne, 1815.	Pond's Maskelyne, 1819.	Pond (1816–21) 1819.
ε . . .	—	—	—	—	+75	+65	+222	+274	+356	+110	—	—	+39	+108	+151	−11	+8	+210	+172	−158	−141
α Andromedæ . .	+350	−96	+120	+140	−75	−44	−62	−69	−66	+68	+70	+410	−9	−48	−5	−12	−47	−73	−12	+7	−63
γ Pegasi	+74	+99	+240	−30	−85	−68	−42	−36	−6	−28	−90	−150	−9	+62	+17	−25	+6	−106	−22	−42	−41
α Arietis	+149	−73	+90	+320	−65	−62	−32	−22	+134	+52	+310	+480	−9	+92	−1	+36	−21	−76	+88	+18	−20
α Ceti	+154	−20	+20	−350	−75	−85	−12	+13	−36	−8	−320	−30	+1	+102	+108	+15	+2	−55	+158	+125	+58
α Tauri	+126	−39	+70	+30	−5	+4	−42	−68	−86	+92	+260	+100	−9	+12	−27	+10	−19	+34	−42	−18	+3
α Aurigæ	+416	−40	+40	+40	+205	+(507)	−82	−173	−306	+39	−50	+20	−49	−38	−46	−75	−22	+24	−52	−59	−7
β Orionis	−570	+36	+160	−210	−15	+164	−2	+13	+34	−5	+90	−230	−9	−28	+41	+3	+1	+94	+28	+25	+68
β Tauri	+836	+145	+120	+90	+25	−54	−62	−100	−146	+19	+0	−60	−9	−8	−21	−31	+7	+52	−32	−36	−17
α Orionis	−74	+34	+170	−320	+35	+26	−12	−26	−56	−72	−20	+170	−9	−8	+3	−70	+2	+105	−22	+6	−8
α Canis Majoris .	−205	+84	+90	+160	+75	−187	−22	+36	−126	+78	+110	−500	+71	−178	+40	−84	+35	+97	−32	−57	+55
α Canis Minoris .	+175	−57	+170	−330	−65	+17	+8	−29	−6	−105	−320	−770	+31	+52	−12	−101	+6	+102	+28	+70	−20
β Geminorum . .	+243	−122	+90	+120	+35	+49	−12	−34	−76	+42	+70	−860	−9	−48	−21	−63	−11	+49	−12	+2	−62
α Hydræ	−749	−140	+180	−340	−135	−159	+8	+47	+124	−11	−260	−120	−39	−58	−23	−21	−17	+130	−52	+27	−45
α Leonis	+246	−121	+180	+00	+25	+80	+18	+16	−6	+33	−140	−360	−39	−118	+6	−30	−8	+54	−22	+26	−39
β Leonis	+174	−101	+140	−170	−15	−83	+18	+22	+34	−34	+110	−610	−29	+42	−53	−10	−2	+17	−62	−28	−37
α Virginis . . .	−182	−43	+40	−260	+115	+103	+58	+42	+24	−44	−230	−70	+21	−38	−45	+22	−8	+26	−52	−45	+43
α Bootis	+49	−38	+80	+280	−45	+1	−2	+13	+34	+55	+130	−1280	+31	+32	−51	−8	−20	+6	−52	−35	−22
α² Libræ	+194	+196	+20	−300	+125	+111	+48	+25	+4	−48	+20	−410	−29	+12	−21	+110	−3	−78	−12	−64	−50
α Coronæ	+98	−68	−120	. . . .	+265	+25	−2	−90	−236	+124	+90	+150	+21	−68	−31	+107	−19	−57	−2	−57	−39
α Serpentis . . .	−401	+115	−50	−600	+5	+28	+18	+18	+24	+0	−30	+130	−9	−18	+21	+111	−1	−20	+58	−3	−26
α Scorpii	−249	+83	+130	+20	−55	−25	−22	−15	+14	−200	+60	+0	+41	−168	+81	−32	+2	−76	+78	+38	+113
α Herculis . . .	+453	−36	−110	. . . .	+55	. . . .	−12	−48	−86	+111	−70	−70	+51	−28	−41	+91	+26	−16	−12	−41	−28
α Ophiuchi . . .	+228	−182	−70	−690	−35	−2	+8	+22	+54	+32	. . .	+70	−9	+22	+11	+38	−22	+39	+48	+61	−36
α Lyræ	+297	−47	+100	+590	+45	+80	−62	−106	−166	+11	−80	+360	+1	+62	−88	+14	+8	−19	−102	−79	−54
γ Aquilæ	+551	+159	−30	. . . .	−45	−6	+88	+132	+214	−2	+80	−380	+11	+132	−17	+20	+15	+9	−2	−26	+2
α Aquilæ	−190	−12	+140	−210	−45	−38	−2	+16	+44	−54	+40	+560	−19	+42	+18	−26	+13	−7	+8	+19	−2
β Aquilæ	−142	+143	+210	. . . .	−45	−29	−32	−26	−16	+2	−150	−90	+11	+32	+3	+28	+17	−19	−12	−18	+4
α² Capricorni . .	+133	−21	+40	−90	−5	+28	−2	−3	+4	−106	+150	+90	−39	−68	−20	+14	−1	−30	−12	−22	+84
α Cygni	+525	−128	+120	−280	−15	+3	−22	−16	−26	+92	−300	+20	−19	+92	+33	−44	−10	−33	+28	+53	−42
α Aquarii . . .	−67	−117	+240	+310	−65	−25	+148	+215	+334	−73	+60	+90	+1	+72	+28	−12	+5	−44	+8	+49	+18
α Piscis Australis	−92	+27	+220	−220	−5	+214	+128	+174	+244	−50	+410	+950	+51	−28	+87	+46	+74	−37	+88	+73	+228
α Pegasi	+365	−00	+220	−30	−105	−73	+8	+40	+124	+1	+180	+70	+1	+92	+21	−24	−4	−67	−2	+25	−17
[v]	—	—	—	—	+1010	+933	+556	+852	+1444	+851	—	—	+344	+952	+527	+665	+219	+838	+618	+622	+676
	—	—	—	—	−1000	−940	−540	−861	−1446	−840	—	—	−352	−948	−523	−668	−235	−822	−622	−630	−675

TABLE IV.

	Pond, 1820.	Pond, 1823.	Brinkley, 1824.	Pond (1821-26) 1825.	Bessel, α Aquilæ, 1825.	Bessel, α Can. Min., 1825.	Struve I., 1825.	Struve II., 1825.	Paramatta, 1825.	Pond (1825-28) 1826.	Bessel, 1827.	Pond, 1827. 1816	Struve, 1830.	Argelander, 1830.	Pond I., 1830, 1816-21.?	Pond II., 1830, 1816-33.	Airy, Camb., 1830.	Airy (F.) 1830, N. A. 1829.	Airy (F.) 1836.	Fallows, Cape Good Hope, 1830.	Fallows (F.) Bessel Tab. Reg. 1830.
ε . . .	+173	−145	+151	− 43	− 40	− 27	− 43	+ 17	—	− 48	+ 19	− 46	− 45	+ 18	−189	− 54	− 26	−172	−140	+ 19	+ 19
α Andromedæ . .	− 66	− 65	− 31	− 47	− 45	+ 67	+ 61	+ 62	−570	− 42	+ 21	− 44	+ 65	− 18	− 38	− 16	− 34	− 68	− 10	. . . .	+ 21
γ Pegasi	− 41	− 55	− 11	− 57	− 98	+ 41	− 17	− 7	−140	− 62	− 39	− 64	− 35	− 28	− 68	− 56	. . . .	. . . .	. . . .	. . . .	− 49
α Arietis	− 10	− 15	− 31	− 7	− 38	+ 34	− 14	− 10	+650	− 2	+ 11	− 14	− 15	− 8	+ 2	+ 4	− 14	+ 2	+ 40	. . . .	+ 21
α Ceti	+ 95	+ 75	+ 49	+ 53	− 19	+ 63	− 7	− 6	+380	+ 68	+ 31	+ 66	− 15	+ 2	+ 52	+ 44	+ 6	+102	− 10	. . . .	+ 31
α Tauri	+ 5	+ 5	+ 29	+ 13	− 27	+ 28	+ 27	+ 27	+330	+ 8	+ 21	+ 6	+ 25	+ 2	+ 2	− 6	− 14	+ 12	− 30	+141	+ 11
α Aurigæ. . . .	− 14	− 5	+ 39	+ 3	− 70	− 24	+ 47	+ 3	+490	+ 8	− 39	+ 6	+ 55	+ 2	+ 22	+ 24	− 44	+ 32	. . . .	. . . .	− 29
β Orionis	+ 74	+ 65	− 11	+ 63	+ 37	+ 30	− 40	− 45	+190	+ 68	+ 41	+ 66	− 45	+ 32	+ 42	+ 24	+ 16	+ 42	+ 0	+ 31	+ 41
β Tauri	− 28	− 15	+ 39	− 17	− 4	+ 16	+ 28	+ 33	−280	− 12	+ 11	− 24	+ 15	− 8	− 8	− 6	− 14	. . . .	+ 0	. . . .	+ 1
α Orionis	− 14	− 15	+ 9	− 17	+ 27	− 2	+ 16	+ 18	+250	− 12	+ 11	− 24	+ 15	− 8	− 18	− 6	− 34	− 8	− 40	+ 11	+ 11
α Canis Majoris .	+ 68	+ 75	− 41	+ 73	+ 86	+ 4	− 3	− 5	+130	+ 88	+ 31	+106	− 15	+ 22	+132	+104	+ 6	+132	+170	+ 41	+ 61
α Canis Minoris .	− 32	−115	− 21	− 57	+ 12	. . . .	+ 1	+ 2	+190	− 72	− 19	− 84	− 5	+ 22	−118	−146	− 4	−248	+ 20	+ 1	− 49
β Geminorum . .	− 82	− 65	− 41	− 57	. . . .	+ 9	+ 9	+ 19	+450	− 52	+ 31	− 54	+ 25	− 8	− 48	− 56	+ 16	− 68	+ 20	. . . .	+ 31
α Hydræ	− 30	− 55	−101	− 57	+ 67	+ 11	− 31	− 29	− 80	− 62	+ 31	− 64	− 25	− 8	− 68	− 66	− 44	− 58	− 40	− 49	+ 41
β Leonis	− 47	− 45	− 9	− 47	+ 63	− 12	− 1	+ 5	+100	− 42	+ 11	− 54	+ 5	+ 2	− 58	− 46	+ 36	− 48	− 10	− 29	+ 11
α Leonis	− 42	− 35	− 1	− 37	+ 67	− 8	− 9	− 1	+380	− 42	+ 21	− 44	− 5	− 8	− 28	− 26	+ 6	− 28	− 20	+ 71	+ 31
α Virginis . . .	+ 52	+ 55	+ 19	+ 23	− 2	− 46	+ 0	+ 5	+180	+ 28	− 29	+ 16	− 5	+ 2	+ 32	+ 34	− 14	+ 72	− 40	− 39	− 29
α Bootis	− 32	+ 5	+ 9	− 7	− 25	+ 25	+ 13	+ 13	+330	− 2	+ 1	− 4	+ 15	+ 2	+ 12	+ 24	− 4	+ 12	− 10	. . . .	+ 11
α^2 Libræ	− 52	− 45	+ 9	− 27	+ 64	− 50	+ 26	+ 28	. . . .	− 22	+ 11	− 24	+ 15	+ 12	− 18	− 36	− 4	− 28	− 10	− 39	+ 1
α Coronæ . . .	− 48	− 35	+ 9	− 17	+ 10	+ 2	− 22	− 29	. . . .	− 12	+ 11	− 14	− 15	− 18	+ 2	+ 4	− 24	− 8	+ 0	. . . .	+ 11
α Serpentis . . .	− 14	− 15	+ 19	− 7	+ 10	− 21	− 34	− 36	+620	− 2	+ 1	− 4	− 45	− 8	+ 2	+ 4	− 34	+ 12	− 40	. . . .	− 9
α Scorpii	+110	+115	+ 39	+113	+ 27	− 95	− 28	− 25	+150	+118	− 19	+116	− 45	+ 32	+102	+114	− 14	+132	− 50	+ 21	− 29
α Herculis . . .	− 43	− 15	− 21	+ 3	+ 10	− 37	− 33	− 37	+510	+ 8	− 9	+ 6	− 35	− 18	+ 22	+ 24	+ 26	+ 2	+ 20	. . . .	− 9
α Ophiuchi . . .	− 36	− 15	− 1	− 17	+ 54	+ 44	− 24	− 30	+140	− 12	+ 61	− 14	− 15	− 8	− 8	+ 4	+ 6	. . . .	+ 10	. . . .	+ 71
α Lyræ	− 66	− 55	− 41	− 57	− 7	+ 35	+ 47	+ 36	+490	− 42	+ 1	− 44	+ 55	− 8	− 28	− 16	+ 6	− 48	. . . .	. . . .	+ 1
γ Aquilæ	− 15	+ 15	+ 19	− 7	+ 8	. . . .	− 10	− 10	+230	+ 8	+ 1	+ 6	− 25	− 8	+ 12	+ 14	. . . .	. . . .	. . . .	− 19	− 9
α Aquilæ	+ 0	− 5	+ 9	− 7	− 2	. . . .	+ 3	+ 3	+260	− 2	+ 1	− 4	− 5	− 8	− 18	− 16	+ 6	+ 2	+ 30	− 29	− 9
β Aquilæ	+ 8	− 5	+ 49	− 17	− 22	. . . .	− 1	− 1	− 10	− 12	− 29	− 24	− 5	+ 2	− 28	− 16	+ 66	. . . .	. . . .	− 69	− 39
α^2 Capricorni . .	+104	+ 95	+ 19	+ 83	− 32	. . . .	− 41	− 37	. . . .	+ 88	− 30	+ 76	− 45	+ 22	+ 52	+ 34	+ 66	+112	+ 30	− 19	− 29
α Cygni . . .	− 42	− 45	+ 39	− 37	− 15	− 26	+ 70	+ 23	+760	− 42	− 19	− 54	+ 75	+ 2	+ 28	− 26	+ 16	− 38	. . . .	. . . .	− 9
α Aquarii . . .	+ 38	+ 15	− 21	+ 13	− 34	+ 57	− 5	+ 2	−400	+ 8	− 9	+ 6	− 5	+ 22	− 28	− 26	− 4	+ 22	− 20	− 19	− 9
α Piscis Australis	+219	+235	− 40	+203	− 83	−164	− 34	. . . .	+130	+ 68	− 99	+206	. . . .	. . . .	+162	+144	. . . .	. . . .	. . . .	. . . .	− 99
α Pegasi	− 20	− 25	− 1	− 37	− 35	+ 28	+ 22	+ 28	+360	− 32	+ 1	− 34	+ 25	− 8	− 28	− 26	+ 26	− 28	− 10	. . . .	+ 1
[v]	+773 −774	+755 −745	+413 −414	+643 −637	+542 −558	+494 −485	+370 −354	+307 −308	— —	+566 −580	+361 −349	+682 −690	+390 −405	+180 −178	+650 −636	+600 −592	+304 −300	+688 −676	+340 −340	+317 −311	+408 −406

TABLE IV.

	Johnson. St. Helena, 1830.	Johnson (F.) 1830. N. A. 1830.	Ast. Soc. 1830.	Pond, 1829–30–31.	Pond, 1833–34–35.	Henderson, Cape Good Hope, 1833.	Taylor, Madras, 1832.
ε	−58	−55	—	−46	−17	+27	−55
α Andromedæ	−72	−35	+360	+76	+4	+23	−15
γ Pegasi	−42	−55	+70	−37	−23	−47	−45
α Arietis	+8	−5	+320	−14	+14	−17	−5
α Ceti	−2	+85	+180	−17	+4	−27	+25
α Tauri	−2	+15	+360	−34	−10	−17	+55
α Aurigæ	−52	+35	+270	−1	−46	+3	+105
β Orionis	−22	+65	+150	−87	+20	+3	+15
β Tauri	+18	−35	+110	−43	−26	−17	+45
α Orionis	+18	−25	+40	+43	−33	+3	+25
α Canis Majoris	−2	+155	+80	−24	+22	+13	+85
α Canis Minoris	−2	−115	+30	+3	−60	−7	−75
β Geminorum	−2	−55	+340	−7	−116	+23	−15
α Hydræ	−42	−55	+260	−54	−20	−17	−105
α Leonis	−2	−55	+320	−4	−23	−7	−25
β Leonis	−12	−35	+190	−4	−53	−17	−55
α Virginis	+18	+15	+130	+29	+20	+3	−55
α Bootis	+48	+15	+310	+73	+17	+23	+85
α² Libræ	+48	−15	−30	−97	+27	−17	−45
α Coronæ	−12	−15	+440	+79	−33	+33	+25
α Serpentis	−2	−5	+100	+33	+24	−57	+5
α Scorpii	+8	+125	−210	−74	+54	−7	−55
α Herculis	+68	+15	+400	+69	+4	+13	+5
α Ophiuchi	. . . .	−5	+360	+29	+10	−7	−5
α Lyræ	−42	−35	+230	+59	−33	+73	−15
γ Aquilæ	+48	+25	+70	+56	+17	−17	−15
α Aquilæ	−2	−5	+100	+23	+34	+13	−25
β Aquilæ	+48	−15	+100	+36	+14	−7	−15
α² Capricorni	−2	+85	+20	−67	+32	−27	+15
α Cygni	−2	−65	+410	+36	+67	+133	−35
α Aquarii	−12	−5	+130	+11	+0	−17	−5
α Piscis Australis	. . . .	. . . .	+80	−104	+67	+3	+135
α Pegasi	+8	−15	+190	+13	+17	−17	−15
[v]	+338 −328	+635 −650	— —	+668 −668	+468 −476	+362 −346	+625 −625

	Taylor (F.) 1832.	San Fernando 1835.	Pond, 1835.	Greenw. 1840.	Greenw. (F.) 1836.	Greenw. 1845.	Gillis, 1840.
ε	−45	+26	−30	+75	−9	+18	+8
α Andromedæ	. . . .	−16	+16	+85	−1	+2	+18
γ Pegasi	−75	+12	−64	+5	−1	+12	+29
α Arietis	+35	+23	+69	+5	+29	−38	−2
α Ceti	+55	+71	+39	−55	−31	+12	−8
α Tauri	−5	+22	+21	−55	−41	−48	+38
α Aurigæ	+25	−124	+63	−85	. . . .	−68	. . . .
β Orionis	+35	+31	+32	−15	+29	−8	+55
β Tauri	−5	+4	+6	−25	−11	−18	−63
α Orionis	−35	+20	−20	−45	−51	−18	−34
α Canis Majoris	+155	+9	+(183)	+5	+49	+2	+112
α Canis Minoris	−145	+13	−(189)	−5	−51	−28	−52
β Geminorum	−65	−25	−73	−55	−101	−28	−119
α Hydræ	−75	+9	−82	−25	−41	−28	−56
α Leonis	−65	−62	−153	−75	−11	−28	−103
β Leonis	−35	+30	−29	−25	−61	+12	+34
α Virginis	+45	+8	+13	−5	+29	+2	−53
α Bootis	+15	−60	+12	−5	−11	+2	−16
α² Libræ	−5	+52	−69	−5	−41	−8	−42
α Coronæ	+15	−88	+39	+15	−11	+2	+21
α Serpentis	+15	−15	+39	+35	+19	+22	+36
α Scorpii	+105	+18	+111	−15	−1	−8	−35
α Herculis	+25	+35	+15	+25	+19	+42	+62
α Ophiuchi	+15	−3	+33	+15	+29	+22	+19
α Lyræ	−35	−90	+47	+15	−51	+22	. . .
γ Aquilæ	+5	+39	+6	+35	+49	+32	+31
α Aquilæ	−25	−4	−17	+5	+9	+22	+44
β Aquilæ	−45	+31	−27	+45	+19	+32	+11
α² Capricorni	+35	+61	+53	+58	+79	+22	+38
α Cygni	−25	−97	−33	+15	. . . .	+2	. . . .
α Aquarii	−45	+37	−35	+25	+89	+22	+40
α Piscis Australis	+155	+63	. . . .	+95	+39	+32	+39
α Pegasi	−35	−6	−23	+5	+29	+12	−1
[v]	+785 −720	+588 −590	+614 −625	+485 −495	+516 −516	+330 −326	+617 −604

	Gillis (F.) Radcliff (F.) N. A. 1840.	Radcliff, 1845.	Pulkowa, 1845.	Greenw. 1850.	B. A. C. 1850.	Edinburgh, 1835–36.	Edinburgh, 1837–40.
ε	−7	−2	+19	−3	—	+28	+37
α Andromedæ	+57	+82	−4	−7	+50	−8	−32
γ Pegasi	−19	+32	−6	+13	+0	−8	−7
α Arietis	+(107)	+62	−22	−17	+80	−13	−19
α Ceti	−2	−18	−3	+3	+20	−18	+8
α Tauri	+5	+22	+24	−17	−10	+2	−15
α Aurigæ	−32	+52	−15	−77	−40	−8	−39
β Orionis	−11	+42	+4	−7	−30	+22	−10
β Tauri	−16	+22	+0	−27	+0	−13	−17
α Orionis	−30	−48	+21	−17	−30	−28	−15
α Canis Majoris	+60	+22	+24	−7	−140	+47	+28
α Canis Minoris	−5	−108	−18	−27	+80	+17	+23
β Geminorum	−89	−98	−9	−27	−60	−3	−15
α Hydræ	−113	−58	−9	−17	−20	−13	−2
α Leonis	−122	−108	+1	−17	−220	+17	+5
β Leonis	−56	−48	−12	−27	−20	+37	+11
α Virginis	−34	−58	−20	−7	−40	+27	+11
α Bootis	−18	−18	−8	−7	−20	−23	−7
α² Libræ	−15	−88	+26	+13	−60	+2	+15
α Coronæ	+60	+42	+1	−17	+100	−38	−21
α Serpentis	+58	+2	+7	+13	+140	−28	+1
α Scorpii	−41	−28	+12	+53	−40	−(128)	+13
α Herculis	−17	+2	+21	+3	+40	−8	+1
α Ophiuchi	+46	+52	+29	+23	+110	+7	+8
α Lyræ	+16	+62	−27	−7	+180	−18	−17
γ Aquilæ	+62	+42	−6	+43	+30	−13	+11
α Aquilæ	+32	+52	−9	+23	+40	+17	+21
β Aquilæ	+24	. . . .	+6	+23	+70	+7	+15
α² Capricorni	+78	+2	−4	+53	+90	−8	+15
α Cygni	−52	−28	−33	−27	+0	−8	−45
α Aquarii	+15	−8	+4	+23	+50	−28	−7
α Piscis Australis	+188	+82	. . . .	+53	+360	+52	+63
α Pegasi	−27	+42	+13	+13	+40	+17	+23
[v]	+701 −699	+716 −714	+193 −205	+352 −356	— —	+271 −284	+272 −268

TABLE IV.

	Edinburgh, 1843–47.	Edinburgh, 1849–59.	Cambridge, 1836–41.	Cambridge, 1843–48.	Cambridge, 1850–54.	Cambridge, 1855–59.	Cambridge, 1860.	Cambridge (F.) 1860. N. A. 1860.	Washington, 1845.	Washington, 1846–52.
ε . . .	+ 76	+ 15	− 74	− 19	− 17	− 22	+ 75	+ 63	− 7	+ 61
α Andromedae . .	+ 45	− 5	− 13	− 8	+ 19	+ 15	− 35	+ 5	− 3	− 2
γ Pegasi	+ 8	− 15	. . . .	. . . .	. . . .	. . . .	− 15	+ 8	+ 17	− 5
α Arietis	− 6	− 11	− 16	− 24	− 1	− 12	+ 15	− 21	+117	− 21
α Ceti	− 10	+ 3	− 24	+ 12	− 9	− 44	. . . .	+ 34	+ 57	− 30
α Tauri	− 22	− 22	+ 13	− 6	+ 3	− 8	− 55	− 61	− 43	− 20
α Aurigae	− 70	. . . .	. . . .	. . . .	. . . .	. . . .	. . . .	− 95	− 93	− 60
β Orionis	+ 2	− 14	− 23	+ 11	− 1	+ 12	− 45	− 9	− 3	− 24
β Tauri	− 16	− 59	+ 35	+ 1	+ 9	+ 19	− 15	− 25	+ 97	− 32
α Orionis	− 18	− 8	+ 4	+ 26	+ 9	+ 10	− 35	− 37	+ 17	− 44
α Canis Majoris .	− 24	− 18	. . . .	− 4	− 7	+ 18	. . . .	−(264)	− 13	− 64
α Canis Minoris .	− 23	+ 18	− 3	− 8	− 3	+ 6	+(125)	+(52)	− 63	− 6
β Geminorum . .	− 24	− 12	+ 29	+ 14	+ 33	+ 20	+ 5	− 47	− 63	− 20
α Hydrae	− 64	− 22	− 33	− 33	− 43	− 33	− 55	− 22	. . . .	− 35
α Leonis	− 38	− 26	+ 7	− 16	− 11	+ 12	− 5	− 47	. . . .	− 20
β Leonis	− 8	− 17	+ 26	− 4	− 29	+ 2	+ 45	− 15	−103	− 21
α Virginis . . .	− 3	+ 1	− 34	− 23	− 17	− 20	+ 15	+ 2	− 43	− 1
α Bootis	+ 12	− 1	− 10	+ 2	+ 31	+ 82	− 25	− 3	− 53	+ 6
α² Librae	− 28	− 28	− 1	− 29	− 33	− 4	− 85	+ 3	+ 27	+ 28
α Coronae	+ 18	− 26	+ 16	+ 11	+ 31	+ 28	− 5	+ 8	− 8	+ 0
α Serpentis . . .	+ 28	+ 6	− 4	+ 1	+ 19	+ 0	− 55	+ 36	+ 47	− 1
α Scorpii	− 4	. . . .	− 28	− 23	− 29	− 14	− 35	− 11	− 73	+ 26
α Herculis . . .	+ 28	+ 26	+ 32	− 11	+ 12	− 28	+105	+ 34	+ 37	+ 0
α Ophiuchi . . .	+ 32	+ 18	+ 31	− 9	− 3	− 48	+115	+ 28	+ 47	+ 31
α Lyrae	+ 30	+ 31	. . . .	. . . .	. . . .	. . . .	. . . .	+ 9	− 93	+ 54
γ Aquilae	+ 35	+ 39	. . . .	+ 13	+ 15	+ 0	+ 45	+ 36	+ 87	+ 33
α Aquilae	+ 52	+ 46	− 9	+ 16	+ 7	+ 20	+ 95	+ 14	− 43	+ 26
β Aquilae	+ 35	+ 18	+ 21	+ 19	− 3	+ 0	+ 25	+ 40	+ 7	+ 15
α² Capricorni . .	+ 18	+ 15	− 4	+ 21	− 9	− 11	− 25	+ 48	− 13	+ 44
α Cygni	− 12	+ 30	. . . .	. . . .	. . . .	. . . .	. . . .	+ 12	+147	+ 23
α Aquarii . . .	+ 6	+ 24	− 28	+ 39	− 9	− 17	− 5	+ 40	+ 27	+ 25
α Piscis Australis	. . . .	. . . .	. . . .	. . . .	. . . .	. . . .	. . . .	+ 50	− 43	+ 85
α Pegasi	+ 36	− 1	+ 2	+ 1	+ 23	+ 7	− 15	+ 1	+ 17	− 2
[v]	+385 −370	+275 −285	+216 −230	+187 −198	+211 −207	+215 −225	+465 −460	+408 −393	+748 −748	+396 −408

	Washington (F.) N. A. 1845.	Pulkowa 1845.	Radcliff, 1845.	Safford, 1855.	Cape Good Hope, 1856.	Cape Good Hope (F.).	Radcliff, 1860.	Greenwich, 1860.	Amer. Eph. I 1860.	Conn. Des Temps, 1860.	Conn. Des Temps, 1869.
ε . . .	+ 7	+ 19	− 2	− 17	+ 33	+ 17	+ 39	+ 17	+ 31	+ 87	+ 18
α Andromedae . .	− 10	+ 4	+ 82	+ 31	+ 57	− 7	+ 31	− 7	+ 9	+ 3	+ 12
γ Pegasi	− 8	− 4	+ 32	− 30	− 33	+ 3	+ 1	+ 3	+ 9	− 17	+ 2
α Arietis	− 4	− 17	+ 62	− 4	+ 7	+ 3	+ 11	+ 3	− 1	+ 33	+ 22
α Ceti	+ 13	− 6	− 18	+ 16	+(207)	+ 23	− 59	+ 23	+ 39	− 57	+ 22
α Tauri	− 51	+ 26	+ 22	− 7	+ 17	− 7	− 29	− 7	− 41	− 47	− 8
α Aurigae	− 98	− 1	+ 52	− 43	. . . .	. . . .	+ 1	− 37	−101	− 87	− 58
β Orionis	− 41	− 3	+ 42	− 8	+ 17	+ 23	+ 11	+ 23	+ 9	− 17	+ 12
β Tauri	− 24	+ 7	+ 22	+ [illegible]	− 3	− 27	− 69	− 27	− 1	− 47	− 38
α Orionis	− 50	+ 20	− 48	− 31	+ 17	− 17	− 29	− 17	− 11	− 57	− 8
α Canis Majoris .	− 19	+ 14	+ 2[illegible]	+(30)	− 3	. . . .	− 39	− 47	−261	−267	−258
α Canis Minoris .	+ 14	− 20	−10	+(34)	+107	+ 13	− 29	+ 3	+ 49	+113	− 48
β Geminorum . .	− 75	− 2	− 98	− 14	. . . .	− 47	− 19	− 37	− 21	− 37	− 18
α Hydrae	− 28	− 16	− 58	− 12	+ 27	− 17	− 29	− 17	+ 9	+ 3	+ 12
α Leonis	−146	+ 2	−108	+ 0	− 3	− 37	+ 21	− 27	− 1	− 47	− 18
β Leonis	− 31	− 10	− 48	− 7	. . . .	− 27	− 39	− 17	+ 9	+ 3	− 8
α Virginis . . .	− 29	− 28	− 58	+ 2	− 53	+ 13	− 29	+ 13	+ 9	+ 3	+ 22
α Bootis	− 31	− 4	− 18	+ 18	− 13	− 17	+ 31	− 17	+ 19	+ 13	− 8
α² Librae	− 36	+ 16	− 88	+ 12	− 63	+ 33	− 9	+ 23	+ 9	− 47	+ 12
α Coronae	+ 48	+ 8	+ 42	− 8	− 3	− 27	− 9	− 17	+ 9	+ 43	− 8
α Serpentis . . .	+ 83	+ 6	+ 2	+ 2	+ 47	+ 13	+ 1	+ 13	+ 39	+ 33	+ 22
α Scorpii	− 46	− 2	− 28	+ 18	− 23	+ 13	− 9	+ 13	+ 9	− 27	+ 12
α Herculis . . .	+ 39	+ 23	+ 2	− 14	− 63	− 37	+ 81	− 27	+ 9	+ 43	+ 12
α Ophiuchi . . .	+ 55	+ 30	+ 52	+ 20	. . . .	− 17	+ 61	− 7	+ 9	+ 73	+ 32
α Lyrae	+ 77	− 16	+ 52	+ 4	− 13	− 17	− 9	− 17	− 21	+ 33	+ 2
γ Aquilae	+ 30	− 6	+ 42	+ 3	+ 47	+ 3	+ 71	+ 3	+ 29	+ 3	+ 2
α Aquilae	+ 13	− 10	+ 52	− 8	− 23	+ 3	+ 31	+ 13	+ 9	+ 13	+ 12
β Aquilae	+ 45	+ 4	. . . .	− 3	+ 7	+ 33	− 39	+ 33	+ 39	+ 13	+ 42
α² Capricorni . .	+ 56	− 13	+ 2	+ 5	− 3	+ 23	− 39	+ 33	+ 39	+ 73	+ 52
α Cygni	− 18	− 20	− 28	+ 24	−153	. . . .	+101	− 7	+ 9	+ 53	+ 12
α Aquarii . . .	+ 38	+ 0	− 8	− 2	+ 77	+ 23	+ 21	+ 33	+ 39	+ 63	+ 62
α Piscis Australis	+237	. . . .	+ 82	+ 19	+ 17	+ 53	+ 21	+ 63	+ 49	+123	+ 72
α Pegasi	+ 14	+ 15	+ 42	+ 4	+ 7	+ 23	+ 1	+ 23	− 1	+ 3	+ 32
[v]	+752 −745	+175 −178	+716 −714	+181 −191	+451 −452	+298 −301	+496 −484	+318 −332	+458 −460	+740 −754	+482 −478

TABLE IV.

	American Ephem. II. Gould, 1860.	American Ephem. II. Gould, 1880.	Wolfers' Tab. Reg. 1860.	Wolfers' Tab. Reg. 1880.	Leverrier, 1870.	Leverrier, 1900.	Paris (Observat'ns.) 1867.	Washington (Observat'ns.) 1871.	Greenwich (Observat'ns.) 1871.
ε . . .	+ 15	+ 9	− 17	− 18	+ 41	+ 58	+ 45	+ 3	+ 41
α Andromedæ . .	+ 10	+ 21	+ 37	+ 61	+ 15	+ 54	+ 0	− 27	+ 19
γ Pegasi	+ 1	− 9	− 32	− 40	+ 11	+ 19	+ 16	− 27	+ 29
α Arietis	+ 1	− 4	− 3	+ 0	− 14	− 8	+ 28	+ 2	− 11
α Ceti	− 4	+ 1	+ 19	+ 25	+ 85	+ 47	− 15	+ 27	+ 29
α Tauri	− 20	− 18	− 8	− 14	− 58	− 86	− 32	+ 15	− 21
α Aurigæ. . . .	− 37	− 39	− 50	− 79	− 138	− 231	+ 58	+ 3	+ 19
β Orionis	+ 3	+ 6	− 10	− 26	+ 2	− 2	+(179)	+ 68	− 21
β Tauri	− 1	+ 9	+ 0	− 7	− 21	− 55	− 67	− 22	− 21
α Orionis	− 25	− 25	− 36	− 57	− 14	− 29	− 44	+ 31	− 1
α Canis Majoris .	−(61)	− (38)	−(29)	− (11)	−(325)	−(166)	− 18	− 93	− 81
α Canis Minoris .	−(23)	−(160)	− (9)	−(133)	− (75)	− (38)	− 57	− 15	− 11
β Geminorum . .	− 32	− 33	− 14	− 14	− 28	− 46	− 19	+ 26	− 1
α Hydræ. . . .	− 30	− 28	− 11	− 7	+ 15	+ 31	+ 2	+ 44	− 11
α Leonis	− 44	− 58	+ 2	+ 13	− 9	− 5	− 18	+ 46	− 21
β Leonis	− 21	− 23	− 7	− 7	+ 1	+ 12	+ 26	− 24	− 11
α Virginis . . .	− 29	− 48	− 1	+ 0	+ 7	+ 19	− 33	− 83	− 1
α Bootis	+ 5	+ 15	+ 20	+ 38	− 14	+ 82	− 3	− 43	+ 29
α^2 Libræ	− 7	+ 0	+ 12	+ 15	+ 6	+ 9	− 52	− 24	− 1
α Coronæ. . . .	+ 5	+ 1	− 8	− 5	− 2	+ 7	+ 18	− 10	− 21
α Serpentis . . .	+ 17	+ 27	+ 4	+ 7	+ 38	+ 51	− 5	− 54	+ 19
α Scorpii	− 21	− 38	+ 18	+ 18	− 3	− 14	− 11	− 14	− 71
α Herculis . . .	+ 15	+ 14	− 17	− 27	+ 11	+ 0	+ 37	+ 14	− 21
α Ophiuchi . . .	+ 32	+ 38	+ 23	+ 32	+ 18	+ 34	+ 5	+ 17	+ 9
α Lyræ	+ 11	+ 8	+ 5	+ 5	− 25	− 51	+(265)	+ 60	+ 19
γ Aquilæ. . . .	+ 20	+ 19	+ 2	− 2	+ 24	+ 22	+ 35	− 4	+ 9
α Aquilæ. . . .	+ 30	+ 30	− 10	− 22	− 4	− 21	+ 24	+ 4	+ 29
β Aquilæ. . . .	+ 27	+ 41	− 4	− 6	+ 40	+ 45	− 6	+ 5	− 11
α^2 Capricorni . .	+ 30	+ 47	+ 6	+ 10	+ 34	+ 45	+ 3	− 29	+ 19
α Cygni	+ 13	+ 19	+ 30	+ 52	− 1	+ 3	+ 88	+ 32	+ 69
α Aquarii . . .	+ 15	+ 15	− 1	+ 1	+ 38	+ 55	+ 35	− 7	− 11
α Piscis Australis	+ 19	+ 9	+ 37	+ 24	+ 36	+ 25	. . . .	+ 75	+ 59
α Pegasi	+ 17	+ 13	+ 3	+ 4	− 8	− 4	− 1	+ 0	− 21
[v]	+271 −271	+ 333 − 323	+218 −212	+ 305 − 313	+ 331 − 339	+ 560 − 552	+ 375 − 381	+469 −476	+357 −369

From an examination of the residuals of the preceding tables, the following conclusions are drawn:—

I. That the magnitude of the accidental errors, in all observations prior to Maskelyne (in their present state of reduction), prevents any safe inference with respect to periodic errors of single period. In general, a certain degree of accuracy must be reached, before it is possible to distinguish with certainty between accidental and periodic errors; and, as I shall presently show, wherever there is an accumulation of accidental errors, periodic errors will be developed in any system of observations, in which there is an irregular distribution of the clock stars in Right Ascension and Declination.

II. That in absolute determinations of Right Ascension, there is no positive evidence of the existence of these errors. An examination of Maskelyne's separate observations will show that the slight periodicity in his later catalogues is apparent rather than real. When we come to more modern observations, we have several instances in which the evidence on this point is quite decisive Airy's Cambridge observations were nearly absolute determinations. For his clock errors, he used stars in the same parallel; and notwithstanding the decisive evidence of periodicity in his provisional places, it is nearly eliminated

from his observations. The Washington observations for 1845 were absolute determinations. Here the positive and negative errors are pretty evenly distributed, but immediately upon the adoption of the differential system, with the Nautical Almanac places as fundamental, the periodicity becomes strikingly apparent. Johnson's St. Helena Catalogue contains far less evidence of periodicity than we should expect, because he applied to his observations a system of corrections by which the errors of single period were partially eliminated. In Brinkley, Struve, and Argelander, and at Pulkowa, the errors in question are very small, if they exist at all.

The three cases which seem to form an exception to this general statement, are, Bessel 1815, Bessel 1825, and Auwers' Cacciatore 1805. With respect to Bessel's observations, it is to be remarked that they depend entirely upon the places of α Aquilæ and α Canis Minoris, the latter having an acknowledged irregular proper motion. In the catalogue for 1815, the place of α Canis Minoris was assumed $.10^s$ too small, and if the Right Ascensions in this region were made entirely dependent on the position of this star, the error should be distributed, not over the whole arc, but over that part only in which the star was used as a standard. In the catalogue for 1825, which is a combination by weights of the results from each star, the periodicity is more marked than in either system taken separately. In the catalogue for 1827, communicated to Pond, errors of single period can hardly be said with certainty to exist. In Auwers' Cacciatore, the periodicity is more marked, but as will be seen, there is apparently an accumulation of accidental positive errors at about 15^h, and we have here the only instance (except Bessel), in which the coefficient of $\sin \alpha$ has a large positive value. This catalogue does not seem to depend in any way upon Leverrier's positions, with which it is compared, but it is rather curious that the coefficients, m and n, are nearly the same for the two catalogues.

III. That the introduction of an excess of positive residuals between 13^h and 23^h, is due to the inequality of the pivots of the new instrument with which Pond began observations for Right Ascension in 1816. It seems to me that the evidence on this point is decisive. These pivots were used till 1825, when steel pivots were inserted, from which it is to be inferred that the first ones were not made of this material. The new pivots not proving satisfactory, they were reground in 1832. I give here, the coefficients a and b for the various catalogues formed by Pond, and I add also, the values derived from the observations just preceding the last correction of the pivots and those immediately following. It is unfortunate for our purpose that the annual results do not appear in the volumes preceding 1829.

EPOCH.	a.	b.
1819 (1816–21)	—.186[3]	+.021[5]
1820 (1816)	—.142	+.021
1823 (1821–23)	—.185	+.020
1825 (1821–26)	—.122	+.018
1826 (1825–28)	—.092	+.015
1830 (1816–33)	—.087	+.022
1829–30–31	+.099	—.015
1833–34–35	—.059	+.009

It is obvious that we have here an explanation of the positive residuals which appear in all subsequent catalogues in the region of 18^h, this point being nearly the mean of the Right Ascensions of stars having large south Declinations. As will be seen, these positive residuals appear in all catalogues depending directly on Pond's observations, and notably in those found in the earlier volumes of the Nautical Almanac. Wherever these catalogues were made the basis of observations with other instruments, these errors were transferred; a little differently distributed but not eliminated.

Pond seems to have assumed that his first pivots became worn unequally. This proves not to have been the case. On the other hand, the steel pivots seem to have undergone a decided change of form, giving nearly opposite results in 1825 and 1832. The change probably took place after 1828, and it is just here that the confusion becomes inextricable, without a re-reduction of Pond's observations.

We must not assume, however, that the values of a and b for the new pivots are entirely due to the pivots themselves, for by the method of observation, the errors of the old pivots were largely transferred to the new. Hence, the later values of a and b are to be considered as only approximately correct; i. e., they are not the values which would have been found if the observations *e.g.* between 1832 and 1835 had been absolute determinations. It is to be noted also, that the change in the values of a and b, indicates that the irregularity is due to an actual change of form in the pivots rather than to flexure or to weakness of the axis.

This tendency to positive residuals for low southern stars by no means escaped the attention of so illustrious an astronomer and so careful an observer as Pond; but after a thorough investigation of the differences between his observations and those of Bessel and Brinkley, he does not seem to have reached any definite conclusion. Nevertheless, α Piscis Australis was finally dropped from his list of time stars, probably on this account. The following remarks on this subject I quote from the Greenwich observations for 1833.

"With all these precautions, we do not find, by comparing the present observations with these of Bradley, made eighty years ago under the same roof, and computed by the same table of refractions, that we can obtain by interpolation, any intermediate Catalogue that shall agree with the observations within the probable limits of error. *This inclines me to my former opinion, that the proper motions of the stars are not uniform*, and that at present our knowledge of them is in a very imperfect state. It has always appeared to me extremely improbable that the proper motions of the stars should be uniform." "And, again, we can hardly obtain a better test of our power of predicting the future positions of the stars, than by trying by the same formula how accurately we can interpolate for the past. In a variety of papers which I have submitted to the Royal Society, I have endeavoured to shew that with us the latter experiment *entirely* fails."

If it is admitted that periodic errors of single period have their origin here, we might expect that when the corrections depending on the Declination are applied, the periodicity should disappear from Pond's observations. But just here is introduced an opposite error through e; that is, the value of e is, on account of these positive residuals, less than it would have been with perfect pivots, the equinox remaining constant. Excluding 8 stars having large south Declinations, the value of e is, in general, about $.04^s$ numerically greater than the

value derived from the whole system. Hence we should expect a general tendency to positive residuals between 0^h and 12^h, when the corrections depending on the pivots are applied. As a matter of fact, the resulting residuals for this interval, are almost precisely represented by the expression, $r \sin a + r \cos a$. And this relation should exist as long as the observations made with pivots of different figure *remain uncombined*. But this combination was made by Pond, and it is on this account that he was unable to satisfy even his own earlier observations. Hence for all observations previous to 1828, the accumulation of positive residuals between 0^h and 12^h, resulting from corrections through a and b, must be distributed over this interval only, by the formula $r \sin a + r \cos a$, but after that date, the errors become by combination so intermingled, that we must distribute them over the whole arc of Right Ascension. In Table V., columns 1, 2, 3, 4, and 5, will be found the residuals previously given, corrected by the values of a and b, given above. In column 6 will be found the corrected residuals for Pond's General Catalogue (of 1112 stars). In the last column will be found the mean of columns 1 to 5, corrected for errors of single period. The following are the derived periodic equations.

$$1829\text{–}31 \quad \ldots\ldots \quad r = -.023^s \sin a - .011^s \cos a.$$
$$1833\text{–}35 \quad \ldots\ldots \quad r = -.024 \sin a + .017 \cos a.$$

TABLE V.

POND . .	1. 1819 1820 1821 Mean.	2. 1821–26.	3. 1825–28.	4. 1829–31.	5. 1833–35.	6. 1816–33.	7. Mean Corr. 1–5.
α Andromedæ . .	− 18	− 6	− 12	+ 42	− 21	+ 6	+ 5
γ Pegasi	− 31	− 43	− 54	− 47	− 17	− 55	− 24
α Arietis	+ 19	+ 23	+ 19	− 38	+ 27	+ 17	+ 0
α Ceti	+ 63	+ 42	+ 59	− 8	− 2	+ 27	− 1
α Tauri	+ 23	+ 30	+ 20	− 48	− 2	− 3	− 6
α Aurigæ	+ 75	+ 78	+ 63	− 62	− 10	+ 72	− 14
β Orionis	+ 27	+ 27	+ 39	− 57	+ 2	− 11	− 6
β Tauri	+ 28	+ 26	+ 19	− 78	− 6	+ 17	− 14
α Orionis	− 13	− 19	− 15	+ 45	− 34	− 17	+ 20
α Canis Majoris .	+ 8	+ 22	+ 48	+ 18	− 4	+ (59)	+ 22
α Canis Minoris .	− 62	− 63	− 78	+ 8	− 63	−(159)	− 14
β Geminorum . .	− 22	− 14	− 21	− 42	− 96	− 36	− 34
α Hydræ	− 83	− 92	− 90	− 25	− 37	− 99	− 42
β Leonis	− 33	− 37	− 37	− 11	− 19	− 48	− 17
α Leonis	− 21	− 21	− 31	− 17	− 46	− 24	− 33
α Virginis . . .	+ 4	− 17	− 4	+ 62	+ 0	− 4	+ 13
α Bootis	+ 10	+ 17	+ 15	+ 53	+ 28	+ 33	+ 25
a^2 Libræ	−104	− 76	− 60	− 57	+ 3	− 80	− 53
α Coronæ . . .	+ 4	+ 23	+ 17	+ 46	− 14	+ 24	+ 5
α Serpentis . . .	− 23	− 10	− 6	+ 36	+ 22	− 8	+ 4
α Scorpii	+ 34	+ 43	+ 65	− 17	+ 20	+ 56	+ 3
α Herculis . . .	− 13	+ 16	+ 16	+ 59	+ 10	+ 25	+ 10
α Ophiuchi . . .	− 19	− 8	− 7	+ 22	+ 14	+ 1	− 7
α Lyræ	+ 10	+ 4	+ 3	+ 10	− 3	+ 19	− 11
γ Aquilæ	− 8	− 3	+ 10	+ 53	+ 19	+ 8	+ 9
α Aquilæ	− 3	− 7	− 3	+ 23	+ 34	− 25	+ 8
β Aquilæ	− 4	− 23	− 18	+ 41	+ 11	− 29	− 3
a^2 Capricorni . .	+ 43	+ 37	+ 52	− 29	+ 10	− 8	− 6
α Cygni	+ 39	+ 35	+ 11	− 22	+102	+ 20	+ 23
α Aquarii . . .	− 1	− 7	− 9	+ 38	− 10	− 46	− 3
α Piscis Australis	+140	+124	+ 8	− 41	+ 29	+ 81	+ 17
α Pegasi	− 2	− 23	− 24	+ 3	+ 23	− 25	− 3
[v]	+527 −460	+547 −462	+464 −469	+559 −599	+354 −384	+ 406 − 518	+159 −291

The remarkable agreement of the residuals in columns 1, 2, and 3, shows conclusively that the observations by Pond were most carefully made; but his pivots have transmitted as a legacy to all subsequent observations, a periodicity which renders their value quite doubtful.

We have here also a partial explanation of the reason why the negative residuals do not follow the irregular motion of Sirius. In the interval between 1816 and 1835, the Right Ascension of Sirius increased about .15^s; but this increase is neutralized by the error depending on the Declination. On the other hand, both causes act together between 1843 and 1868; and it is during this interval that the periodicity of all observations depending on Pond is the most marked. It should also be remarked, that Pond's provisional catalogue, brought forward from Maskelyne, contains slight errors of single period.

IV. That the position of the zero point of the errors depending on the Declination is entirely due to the distribution of the fundamental stars; and that the reason why it remains unchanged, is because these stars retain the same relative positions. The mean Declination of the stars under consideration is about +9°. Had the stars having large south Declinations, been all situated in the first quadrant, the zero points would have been differently located.

V. That the periodic errors of single period have been transmitted to subsequent observations in proportion to their dependence on Pond's catalogues of 720 and 1112 stars, and that the Nautical Almanac, has been largely instrumental in the perpetuation of these errors. The errors of single period found in the Greenwich observations under Airy, are to be ascribed to similar errors in the provisional catalogue adopted in 1836. It would have been fortunate if the first Cambridge Catalogue had been adopted instead. Airy's Cambridge system was continued at that observatory till 1860; and as will be seen by simple inspection of the various sets of residuals, the errors are very small and are mostly due to the Cambridge pivots. But in 1860 there was a return to the Nautical Almanac positions of the clock stars, and immediately the periodicity becomes apparent. The Edinburgh observations for 1835–36 depend on Bessel's Tabulae Regiomontanæ; those for 1837–41, on the mean of the Greenwich, Cambridge, and Edinburgh observations for each preceding year; while those subsequent to 1841, depend on the Greenwich clock stars, the places being communicated each year. In the first case, the errors follow those of the Tabulae Regiomontanæ quite closely; in the second, the errors of single period are partially eliminated through the values of a and b, peculiar to each instrument; while in the last case, the errors of the Greenwich system are largely reproduced. The errors depending on the Declination are not as apparent previous to 1860, as since that date.

VI. That the variations in the relative values of m and n are due to two causes: viz, —

(a). To the configuration of the clock stars.

(b). To the declination errors peculiar to each instrument.

Under the first head, the most marked case is that of Oxford. The value of n is persistently larger than for other observatories. I apprehend the reason for this is to be found in the fact that in the earlier observations and especially in those made in 1841–2 but few of Maskelyne's clock stars between 17^h and 24^h were used; α Lyræ, α Aquilæ, β Aquilæ, α^2 Capricorni, α Cygni, and α Piscis Australis being omitted. Thus the weight of the errors of the provisional

catalogue fell between the first and the third quadrants. Had Mr. Johnson used the Greenwich clock stars for the same year, he would not have detected the inequality mentioned in the volume for 1841. We find here also an explanation of the difference often found between day and night observations. In January and July the residuals reach their maximum value, but with opposite signs. During these months, therefore, the difference between day and night observations may amount to nearly $.10^s$. On the other hand, in May and November, no appreciable difference will be observed, the observations for these months being near the zero points. It may be found also that the large difference in the values of α and β from the Washington observations of 1866 and 1867, as determined by Professor Newcomb, may be due to the difference in the relative number of observations made in corresponding months of different years.

Under the second head, the most marked cases in more modern observations are Paris, Edinburgh, Washington II., and Harvard College, though in the last case, the coefficients, depending on an average of 6 observations for each star, must be considered as only approximately correct. As has been already remarked, the errors of single period from this cause are in some cases diminished; in others augmented.

To conclude briefly:—

I. The periodic errors of single period existing in observed Right Ascensions, are in no sense inherent in the observations themselves, but are entirely transferred from the provisional places of the clock stars on which they depend.

II. The accumulation of positive residuals in the region of 18^h, is due to the unequal pivots of the Greenwich Transit, erected in 1816.

III. The accumulation of negative residuals in the region of 6^h is due, partly to the general *drift* in the direction of the motion of Sirius and Procyon, and partly to errors developed indirectly from the combination of observations made with unequal or irregular pivots.

IV. The errors thus accumulated are distributed over the whole arc of Right Ascension by means of the formulæ:—

$$m \sin \alpha + n \cos \alpha.$$
$$m' \sin 2\alpha + n' \cos 2\alpha.$$

If the results which I have reached, are accepted as true, it is evident that the speedy return to absolute determinations of Right Ascension is a matter of vital consequence. I venture to suggest that the time has come when astronomers should, by concurrent action, determine which stars shall be regarded as fundamental. If the true elements of *e.g.* 100 stars, properly distributed in Declination, could be decided by recognized authority, and then if all differential observations could be made to depend on these stars only, it would be possible to reach a degree of accuracy unattainable under the present system. For the future, we ought not to be compelled to depend on theory in order to harmonize observations. Theory may be useful in making available, data already accumulated, but observation must be the last resort.

VIII.

SCIENTIFIC SURVEY OF THE STATE OF MASSACHUSETTS.

Read, April 14, 1874.

MEMORIAL.

TO THE HONORABLE THE GENERAL COURT OF MASSACHUSETTS:

The American Academy of Arts and Sciences respectfully presents the following Memorial, urging a new and thorough Scientific Survey of the Commonwealth.

It is now more than forty years since the State of Massachusetts began a survey of its territory, the results of which were published in a series of Reports upon the geology, zoölogy, and botany of the State, with a map and a geological chart. It was the first public survey undertaken in this country, and was followed by similar ones carried on by the other States and by the General Government. Massachusetts has the honor, not only of originating this series of surveys, but of giving to the country a large proportion of the scientific men who conducted those of the other States. The survey was at once of great practical value to the Commonwealth, and a school for scientific education.

The several Reports thus published have been absorbed by the public, and it is now impossible to procure them; the State recognized this fact when it ordered the republication of two of them; and the demand for others of the series suggests the pertinent inquiry whether a simple republication or a revised edition of one and another of the Reports would meet the demands of the people. In the main, the Reports represented fairly the condition of science at the time they were made; but the lapse of one generation has witnessed such progress in the methods of scientific investigation, and such an addition to the store of knowledge, that, though the Reports contain much valuable material, most of them are now incomplete and to some extent antiquated. The time has come when a new survey is necessary, more thorough and comprehensive than the old, as the method and knowledge supplied by science now are in advance of what was at the command of the men of that day.

The State was the first to order a scientific survey, and it should not allow itself to be the last to take advantage of the developments of later study. Within the past few years there has been great activity in many of the States in this direction; and there have been published, or are in process of publication, Reports which leave ours far behind; while the surveys undertaken in Europe, even by the smaller and less favored countries, have been much more thorough and systematic than any executed in this country.

The publications of such a survey as is now proposed should embrace a detailed topographical map, on a scale of about an inch to a mile, maps colored to show the distribution of rock-formations and economic minerals, with charts on a larger scale of particular localities, having special interest or importance; sections and explanatory text to accompany these maps, embracing descriptions and analyses of the rocks and ores and of the waters, and investigations into the strength and durability of our building-stones; full descriptions and truthful illustrations of the animals and plants, including their natural history, transformations, and relations to man and his requirements.

In carrying out the survey, the State could take advantage of the provision made by Congress, by which any State undertaking a topographical survey of its territory is empowered to call upon the United States Coast Survey to make the preliminary triangulations; so that the State is at once relieved of a very important part of the work to be done. In making these triangulations, the Coast Survey utilizes the experience of local Professors and their students; and in the same way it would be entirely feasible, in following the trigonometrical with the topographical survey, to employ the services, in different parts of the State, of the same persons. The survey would thus become at once a most valuable auxiliary to scientific education, by giving the younger men in our schools of science and technology an opportunity to put their studies to practical use.

The material interests of the State call urgently for this survey. A detailed topographical map on the scale above indicated, accompanied by tables representing the land-slopes and the areas of the river bottoms, would be of great value in guiding plans of public or local improvement. The extension of the rocks of the Rhode Island coal-field into our State makes it important to decide once for all the question whether these rocks contain coal-seams of economic value. It may reasonably be expected that new industries would be seen to be practicable, and experience has shown that an important result of such surveys is to prevent the waste of capital and labor in unfruitful en-

deavors, as well as to direct where industries will best flourish; more advantageous methods of carrying on present enterprises would be established, and our natural resources economized; as a single illustration, the results already reached by the appointment of fish-commissioners may be cited.

But the survey is urged on a still higher ground. The education of its citizens has always been the cherished aim of Massachusetts. There is no society of scientific men within the limits of the State, no educational institution, that can do what lies simply within the power of the Commonwealth to effect: namely, to furnish old and young, and especially those receiving a common-school education, with the means of acquiring a precise and thorough knowledge of nature, as manifested in the familiar objects about them. To this end your memorialists urge that the Reports under the proposed survey should, as far as possible, be prepared with special reference to an intelligent use by the people; and that, instead of being distributed gratuitously, they should be sold through the ordinary agencies at a slight advance upon the cost, so as to enable the State to pay the authors from the proceeds of the sales, and to recover the greater part of its original outlay, without placing the books beyond the reach of persons of moderate means. Such a mode of publication would unquestionably be the most economical for the State, and the most certain to bring the books directly and naturally into the hands of those who would value and use them.

(Signed), CHARLES FRANCIS ADAMS, *President.*

JOSIAH P. COOKE, Jr., *Corresponding Secretary.*

IX.

NOTES ON COMPOSITÆ AND CHARACTERS OF CERTAIN GENERA AND SPECIES.

BY ASA GRAY.

Read, May 12, 1874.

THIS paper is a continuation and conclusion of one which was communicated to the Academy a year ago, and printed at the close of the preceding (the 8th) volume of the Proceedings. It chiefly concerns Californian genera, and the changes which it becomes necessary or proper to make on account of the new revision of the *Compositæ* by Mr. Bentham in the second volume of Bentham and Hooker's Genera Plantarum; and it indicates a few slight corrections in that admirable and arduous revision, as well as the somewhat different conclusions to which I have been led in respect to the circumscription of two or three genera.

Characters of a small number of new species of other orders are appended at the close.

MADIEÆ. A characteristically Californian subtribe, with one *Madia* dispersed to Chili, and two remarkable genera in the higher region of the Sandwich Islands. In the Genera Plantarum alternate leaves are assigned to all our North American genera; but the lower or lowest are commonly opposite, and all but the uppermost are prevailingly so in Nuttall's *Anisocarpus* and my *Hemizonella*. It was by an oversight, as the context shows, that the achenia of *Anisocarpus* were said to be obcompressed in the Flora of North America.

MADIA Molina. The reduction of *Madaria* DC. and *Madorella*, *Anisocarpus*, *Amida*, *Harpæcarpus*, and some other genera of Nuttall to *Madia*, the counterpart of what I had already done in *Layia*, is

freely to be accepted. The species may be most conveniently and naturally arranged under three subgenera, as below.*

* MADIA Molina.

§ 1. MADARIA. (*Madaria* DC. & *Anisocarpus* Nutt.) Ligulæ conspicuæ, exsertæ, plurimæ: flores disci plurimi, aut omnes aut centrales steriles, corollis pubescentibus.

* Achenia seu ovaria disci pappo tenui fimbriato-paleolato vel plumoso superata. — *Anisocarpus* Nutt.

1. M. NUTTALLII Gray. Hirsuta, gracilis, 1–2-pedalis; foliis caulinis plerisque oppositis denticulis seu dentibus gracilibus sæpe instructis; capitulis mediocribus longe tenuiter pedunculatis; involucri squamis breviter apiculatis; ligulis majusculis; acheniis radii obovato-falcatis lateribus planis enerviis (ovariis) disci sterilibus, pappo brevi. — Proc. Am. Acad. 8, p. 391. *Anisocarpus madioides* Nutt.

2. M. BOLANDERI Gray, l. c. Villoso-hirsuta, 2–4-pedalis; foliis plerisque alternis, inferioribus elongatis; capitulis majoribus racemosis; involucri squamis (modo subsequentis) ultra partem fructiferam lineari-appendiculatis; paleis receptaculi linearibus distinctis; ligulis breviusculis; acheniis (etiam radii parce hirtellis) elongatis, radii lanceolato-falcatis faciebus 1–2-nervatis; disci exterioribus ut videtur fertilibus; pappo e paleolis setiformibus barbellato-plumosis inæqualibus corolla paullo breviore. — *Anisocarpus Bolanderi* Gray, Proc. Am. Acad. 7, p. 360. — The ray-akenes, in no. 499 of the distribution of Kellogg and Harford, also show a rudimentary pappus?

* * Achenia seu ovaria omnia calva. — *Madaria* DC.

3. M. ELEGANS Don, Bot. Reg. t. 1458. Spithamæa ad tripedalem; involucri squamis lineari-appendiculatis; ligulis (in majoribus 10–15, in depauperatis 5–9) elongatis aut luteis concoloribus aut basi atrorubris, lobulis angustis; receptaculo convexo hirto-fimbrillifero; ovariis disci inanibus; acheniis radii oblique obovatis, areola epigyna depressa. — *Madaria elegans* & *M. corymbosa* DC. The figure of *M. corymbosa* in Endlicher's Iconographia is from a dried specimen, with rays poorly developed.

4. M. RADIATA Kellogg, Proc. Calif. Acad. 4, p. 190. Bi-tripedalis, viscido-pubescens et glandulosa (nec hispida); involucri squamis breviter appendiculatis; ligulis 9–20 aureis lato-oblongis obtuse tridentatis; receptaculo plano subglabro; floribus exterioribus disci fertilibus; acheniis radii anguste obovato-falcatis rostello brevissimo recurvo apiculatis, disci rectiusculis subclavatis faciebus angulatis, areola epigyna depressa, centralibus inanibus. — Ligules half an inch long, abrupt at base, the expanded head, including these, sometimes two inches in diameter. A plant was raised in the Cambridge Botanic Garden, in 1878, but no good seed was saved.

§ 2. EUMADIA. (*Madia* & *Amida* Torr. & Gray. *Madia*, *Madariopsis*, *Madorella*, & *Amida* Nutt.) Ligulæ breves inconspicuæ, 12–1, quandoque nullæ: disci flores plurimi vel pauci, omnes fertiles; corollæ tubo pubescente: receptaculum planum, ambitu excepto nudum glabrum.

5. M. SATIVA Molina. — California is perhaps the birthplace of this species, to which must belong, as mere varieties, var. CONGESTA, *M. capitata* Nutt., the com-

HEMIZONELLA. *Hemizonia* § *Hemizonella* Gray, Proc. Am. Acad. 6, p. 548. Upon a review of the group, it seems proper that these little plants should constitute a genus. They differ from *Hemizonia* not only in the reduction of the disk-flowers to unity, but in the complete enclosure of the achenia in the involucral scale, after the manner of *Madia*, yet with a difference which answers to the different form of the achenium itself: their leaves also are mainly opposite, in which they are unlike both *Harpæcarpus* and *Hemizonia*. The species are as follows:—

HEMIZONELLA MINIMA. *Hemizonia* (*Hemizonella*) *minima* Gray, Proc. Am. Acad. 6, p. 548.

HEMIZONELLA PARVULA. *Hemizonia parvula* Gray, l. c.

HEMIZONELLA DURANDI. *Hemizonia Durandi* Gray, l. c.

HEMIZONIA DC. The only change by the Genera Plantarum is the incorporation of *Calycadenia*, which had become inevitable or nearly so. Some of the external disk-flowers not rarely perfect their achenia. To most of the species of *Hemizonia* the character "achenia lævia" is inapplicable. When the genus was worked up for the Flora of North America, several species were not well understood. All are annuals, or at most biennials. The subjoined summary of the arrangement adopted for the forthcoming Flora of California may be use-

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mon *Tarweed* of the eastern part of California; var. RACEMOSA, *Madorella racemosa* Nutt., the achenia of which are with or without nerve-angled sides; and var. DISSITIFLORA, *Madorella dissitiflora* Nutt., a depauperate or slender form, with fewer-flowered heads and shorter and broader achenia.

6. M. GLOMERATA Hook. Fl. Bor.-Am. *Amida gracilis* and *A. hirsuta* Nutt., forming one and a very distinct species of true *Madia*, having ray-flowers reduced to four, three, or even to one or none at all, the disk-flowers also very few. The akenes are straightish and somewhat fusiform, sometimes flattened and merely nerved, but at maturity those of the disk almost prismatic, having 4 or 5 acute angles. With no. 285 of Hall's Oregon collection some *M. sativa* was mixed in the distribution.

§ 8. HARPÆCARPUS. (*Harpæcarpus* Nutt.) Ligulæ brevissimæ 4–8: flos disci unicus intra cupulam 3–5-dentatam, fertilis: corollæ glabræ: achenia radii obovato-lunata, apiculata, disci rectum oblique obovatum. Capitula pusilla, pedunculo filiformi, involucri squamis apice vix appendiculatis.

M. FILIPES Gray, Proc. Am. Acad. 8, p. 391. *Sclerocarpus exiguus* Smith? *Harpæcarpus madarioides* Nutt.; Torr. & Gray, l. c. *H. exiguus* Gray, in Bot. Mex. Bound. p. 101. On a wider comparison of specimens, I conclude that we have only one species of this group. The size of the achenia and the prominence of their beak-like apiculation are variable.

ful.* The species fall under three very well-marked subgenera; — to which I am obliged to add a fourth for Kellogg's *Calycadenia plumosa*,

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* HEMIZONIA DC., Benth. & Hook. (*Hemizonia, Hartmannia, & Calycadenia* DC. *Hemizonia & Calycadenia* Torr. & Gray.)

§ 1. HARTMANNIA. (*Hartmannia* DC.) Achenia fertilia (radii) opaca, sæpe rugosa, valde gibbosa, areola epigyna parva ex angulo interno papilloso- vel rostellato- exserta. Flores flavi.

* Receptaculum planum, præter marginem cupulato-paleaceum nudum. Achenia radii demum rugosa; disci sterilia sæpius inania, pappo paleaceo vel squamellato rariusve nullo. (*Hartmannia* DC.)

+ Ligulæ 5, latæ, tubulo incrassato: fl. disci 5–6, pappo paleaceo donati. Capitula parva.

1. H. RAMOSISSIMA Benth. Bot. Sulph.

2. H. FASCICULATA Torr. & Gray, Fl. N. Am. *Hartmannia fasciculata* DC. Prodr. *H. glomerata* Nutt.

+ + Ligulæ 12–20, longiores, tubulo glanduloso gracili: achenia fertilia biseriata: fl. disci plurimi. Capitula mediocria, ramos subcorymbosos terminantia.

3. H. ANGUSTIFOLIA DC. Diffusa; foliis caulinis integerrimis; ligulis 12–15; pappo fl. disci aut nullo aut squamellato minimo. — *H. multicaulis* Hook. & Arn.? *H. decumbens* Nutt. Pl. Gamb. — Var. BARCLAYI: acheniis disci minus inanibus pappo paleaceo laciniato haud inconspicuo, radii permaturæ magis incurva insigniter rostellato. Monterey, Barclay. San Luis Obispo, Brewer.

4. H. CORYMBOSA Torr. & Gray. Erecta, corymbosa; foliis caulinis plerisque pinnatifidis; ligulis 15–25; pappo florum disci squamellato minimo, ovariis abortivis. — *H. angustifolia* Benth. Pl. Hartw. *H. macrocephala* Nutt. Pl. Gamb. *H. balsamifera* Kellogg. *Hartmannia corymbosa* DC.

* * Receptaculum planum, paleis 8–10 discretis, singulis achenium sterile calvum disci semi-amplexantibus. Achenia radii 5, lævia, glabra. Capitula virgato-racemosa, angusta, ligulis latis brevibus. Herba habitu glandulisque fere *Calycadeniæ*.

5. H. VIRGATA Gray, Bot. Mex. Bound. p. 100.

* * * Receptaculum convexum vel conicum, multiflorum, totum paleaceum, paleis discretis. Ligulæ plurimæ, breves. Achenia radii 2–3-seriata, parum rugosa, disci exteriora vix inania. Capitula mediocra. Folia inferiora pinnatifida. (*Hemizonia* sect. *Olocarpha* DC. pro parte.)

+ Pappus nullus.

6. H. MACRADENIA DC. Folia ramealia et bractealia glandula truncata superata; involucri squamæ etc. glandulis longe valideque stipitatis ornatæ; receptaculo conico.

7. H. PUNGENS Torr. & Gray. — *Hartmannia pungens* Hook. & Arn.; Hook. Ic. Pl. t. 334. — Receptaculi paleæ spinuloso-acuminatæ.

which is evidently of this genus, although it overpasses the limits of the subtribe in having a pappus in the ray, while the disk-akenes may per-

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+— +— Pappus e paleolis linearibus basi subconcretis apice fimbriolato-barbatis constans: paleæ receptaculi muticæ villoso-barbatæ.

8. H. FITCHII Gray, Bot. Whippl. p. 52. — Foliis lobisve in spinulam desinentibus pungentibus (ut in præcedente) horrida.

§ 2. EUHEMIZONIA. (*Hemizonia* DC. quoad spec. typica utraque sectione.) Achenia fertilia (radii) lævia, parum obliqua, areola epigyna depressa vix excentrica, basi stipite tenui manifesto inflexo; disci abortiva, pappo nullo. Paleæ receptaculi convexi discum totum occupantes, interiores tenues, exteriores magis herbaceæ. Folia subintegerrima, villosæ. Capitula mediocria, subcorymbosa, multiflora, ligulis alte trilobis sæpius biseriatis. Flores lutei vel albi, meridiani.

9. H. CONGESTA DC. — Flores lutei: paleæ exteriores receptaculi fere discretæ.

10. H. LUZULÆFOLIA DC. — *H. sericea* Hook. & Arn. *H. rudis* Benth. Bot. Sulph.; forma æstiva vel autumnalis, ramosissima, microcephala, glanduloso-viscosissima. — Flores albi: receptaculi palearum series exterior in cupulam concreta.

§ 3. CALYCADENIA. Achenia radii fertilia obovoideo-triangularia, subgibbosa, areola epigyna parum excentrica, aut glabra aut parce pilosa; disci longiora, deorsum angustata, sæpius quadrangulata, pappo paleaceo superata, omnia ovulifera, exterioria nonnulla fertilia. Paleæ receptaculi plani inter discum et radium, involucrum interius efficientes. Folia angustissima, integerrima, superiora cum bracteis etc. sæpissime glandulis magnis disciformibus vel acetabuliformibus superata vel consperea. Capitula parvula, ligulis 1–7 latis palmato-trifidis vel tripartitis. Flores albi rariusve lutei, anthesi in nonnullis (an omnibus?) vespertini et matutini.

* (*Osmadenia* Nutt.) Paniculato-ramosissima, effusa, glandulis *Calycadeniæ* adempta, capitulis ramulos filiformes terminantibus: achenia rugosa, basi tenuiter stipitata, apice rostello crasso superata.

11. H. TENELLA. *Osmadenia tenella* Nutt. *Calycadenia tenella* Torr. & Gray.

* * Laxe paniculato-ramosa, capitulis axillaribus terminalibusque subsessilibus, bracteis foliisque nonnullis glandula acetabuliformi brevi-stipitata terminatis: achenia lævia nec basi nec apice producta.

12. H. FREMONTII. *Calycadenia Fremontii* Gray, Bot. Mex. Bound. p. 100. — Flores radii 5–7, disci ad 20.

13. H. PAUCIFLORA. *Calycadenia pauciflora* Gray, l. c. — Flores radii solitarii, disci sæpius 8.

* * * (*Calycadenia* DC.) Virgata, sæpius stricta, axillis capituliferis, glandulis acetabuliformibus seu disciformibus haud raris: achenia apice truncata, areola epigyna majuscula parum elevata.

+— Molliter pubescens, capitularum glomerulis axillaribus laxis subpedunculatis.

14. H. MOLLIS. *Calycadenia mollis* Gray, Proc. Am. Acad. 7, p. 360. — This

haps all become fertile; and the plumose disk-pappus is very like that of *Blepharipappus*, a slender form of which in the Kew herbarium was in the Genera Plantarum mistaken for a *Hemizonia*. Moreover,

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is a handsome species, with its copious bright white flowers displayed towards sunset and through the early morning; and is well worthy of cultivation.

+– +– Glaberrima, foliis infimis tantum setoso-hispidulis, capitulis dissitis solitariis; pappi paleis brevibus muticis, raro nullis.

15. H. TRUNCATA. *Calycadenia truncata*, DC.

+– +– +– Setoso-hirsuta vel hispida, præsertim ad margines foliorum et bractearum, capitulis in axillis sessilibus solitaris vel glomeratis, pappi paleis aut fere omnibus aut alternis aristato-subulatis.

16. H. DOUGLASII. *Calycadenia villosa* DC. — Flores ut dicitur lutei: capitula in axillis solitaria, sæpius dissita. — In transferring this, I venture to change the specific name. It is seldom if ever villous, and usually hardly at all hirsute. Unless the color of the flowers may be relied on, it will be difficult to distinguish the species from slender forms of the following.

17. H. MULTIGLANDULOSA. *Calycadenia multiglandulosa* & *C. cephalotes* DC. — Flores albi, quandoque carnei? Capitula saltem superiora sæpius glomerata, nunc spicato-conferta.

§ 4. BLEPHARIZONIA. Achenia omnia turbinata fere æquilatera, hirsuta, acute 10-costata, areola epigyna majuscula centrali haud prominula, intima disci tantum sterilia, omnia pappifera! Pappus fl. disci ex aristis circiter 20 æqualibus barbato-plumosis, radii e coronula pateræformi subscariosa margine ciliata constans! Cæt. fere *Calycadeniæ*.

18. H. PLUMOSA. *Calycadenia plumosa* Kellogg, in Proc. Calif. Acad. 5, p. 49. —Near Stockton, California, sent by an unknown collector to Dr. Kellogg, from whom I have a branch. An anomalous species, which it is wonderful should have been overlooked, if it really grows in a district so often traversed by botanists as the neighborhood of Stockton. It has three remarkable peculiarities,— 1. The 10-ribbed or acutely 10-nerved achenia; 2. A distinct coroniform pappus to the ray-achenia, in which it departs from the character of the subtribe, but something like it is occasionally seen in *Layia;* 3. The pappus of the disk-akenes (most of them fertile) consists of plumose awns instead of naked paleæ, in this respect approaching *Blepharipappus;* but the style-branches, &c., are as in *Calycadenia*. Dr. Kellogg describes the flowers as yellow, but they may have been white. The *Calycadenia*-like glands are copious and light-colored. Chaff of the receptacle not forming a cup, as described by Dr. Kellogg, but of distinct scales, occupying more than one series. Moreover, the achenia are not "obcompressed," nor is it clear what is meant by their being "imbedded in the densely villous disk."

Excludendæ. *H.? ciliata* Torr. & Gray (*Hartmannia ciliata* DC.) is *Oxyura chrysanthemoides* DC. = *Layia chrysanthemoides* Gray. — *H. filipes* Hook. & Arn. is *Lagophylla filipes* Gray. — "*H. sp.* coll. Bridges, no. 118," Benth. & Hook. Gen. l. c. = *Blepharipappus scaber*, Hook. var.

a form of *Blepharipappus scaber* (var. *subcalvus*) occurs, in which the pappus both of the ray and disk is reduced to a mere vestige. The style of the disk-flowers of that genus, however, is characteristic, but the distinction between the *Madieæ* and the *Galinsogeæ* is evanescent.

LAYIA Hook. & Arn., Gray, Pl. Fendl., with *Oxyura* DC. added (as in the Genera Plantarum), is best disposed under three sections.

The first, *Madaroglossa*, has the receptacle chaffy only at the margin between the ray and the disk (if also among some of the outer flowers, only inconstantly so); the stout bristles or slender awns of the pappus long-plumose or villose (or within woolly) below the middle; akenes all narrow, those of the ray crowned with a protuberant and annular or obscurely cupulate epigynous disk, sometimes imitating a coroniform pappus (abnormally, they now and then bear rudiments of true pappus); and all the species are beset with more or less copious dark stipitate glands among the hispid pubescence. The white-rayed species are *L. glandulosa* Hook. & Arn. (with a Californian variety, *rosea*), known by the crisped and interlaced wool on the inner side of the pappus-bristles; and *L. heterotricha* Hook. & Arn., with the less copious wool all straight, none of the interior crisped. *L. carnosa* Torr. & Gray may also be referred to this section, its very short rays seeming to be white, the pappus as in the preceding. The yellow-rayed species are *L. hieracioides* Hook. & Arn., with very short rays; *L. gaillardioides* Hook. & Arn., and *L. elegans* Torr. & Gray, with ample rays, the latter known by its pappus being similar to that of *L. glandulosa*.

The second section, *Callichroa*, is very like the yellow-rayed portion of the first, except that the setæ of the pappus (5 to 25) are naked; in *L. pentachæta* Gray, slender and smooth, sometimes reduced to two or three, or even with no pappus at all. At Forest Hill, Placer Co., California, Dr. Bolander gathered specimens apparently growing with this species and undistinguishable from it, except by the pappus, which refers them to *L. gaillardioides*. Of *L. platyglossa* Gray, there is a variety, *breviseta*, with pappus very much shorter than the corolla or achenium, collected near Los Angeles by Dr. Bigelow.

The third section, *Calliglossa*, has chaff to all the disk-flowers, obovate or oblong akenes, the pappus of subulate awns or more dilated paleæ, or none at all; the scales of the involucre woolly or woolly-ciliate within at the infolded portion; and there are no stipitate glands.

Its larger subdivision, with a pappus and a flat receptacle, contains *L. calliglossa* Gray, with some marked varieties as to the awns of the pappus, and *L. Fremontii* (*Calliachyris* Torr. & Gray), with conspicuously paleaceous pappus and some sparse long *villi* interposed or barely

adnate to their base, which seem to represent the *villi* of the pappus in *Madaroglossa*, but are hardly distinguishable from those that clothe the achenium. The smaller subdivision, containing *L. chrysanthemoides* (*Oxyura* DC.), has a very convex receptacle, glabrous disk-akenes, and no pappus.

L. Douglasii Hook. & Arn. remains an obscure and ambiguous species. It is very briefly described from a specimen collected by Douglas "between the Narrows and the Great Falls of the Columbian River;" and the character "pilis eglandulosis setosa" implies that it agrees with the *Calliglossa* section in having no stipitate dark glands, while the rays are said to be "white." Doubt is not removed by the inspection of two or three disk-flowers which I possess from the specimen in the Hookerian herbarium. The ovary in these is glabrous; and the pappus consists of rather stouter and flatter awns than in any *Madaroglossa*, but fringed near the base with scanty long-villous hairs. It remains uncertain, therefore, whether the species belongs to *Madaroglossa* or *Calliglossa*, more likely to the former, unless the receptacle should prove to be chaffy throughout.

The tribe HELENIOIDEÆ, as now constituted, differs from the *Helenieæ* of De Candolle in the exclusion of the *Madieæ* and the inclusion, as sub-tribes, of the *Flaverieæ* and the *Tagetineæ*, the latter embracing the *Pectideæ*. The separation of the *Euhelenieæ* and the *Bærieæ* into equivalent subtribes does not seem to be justified by any clear and tangible differences. The *Helenioideæ* are almost all American. For the Flora of California, in which they are largely represented, the following subtribes are adopted: 1. *Jaumieæ*, with regularly imbricated and broad involucral scales; 2. *Riddellieæ*, with persistent rays in the manner of *Zinnia* (includes *Whitneya* as well as *Riddellia*); 3. *Helenieæ* with nearly equal scales to the involucre, deciduous rays, and no oil-glands; 4. *Tagetineæ*, with oil-glands. The *Flaverieæ* are not represented in California.

JAUMEA Pers. The close relationship of *Coinogyne* Less. with the Buenos-Ayrean *Jaumea* was suggested in Bot. Mex. Boundary and elsewhere: their union by Bentham is no doubt to be sustained, however it may be as respects *Espejoa* and *Chæthymenia*. But the Californian *C. carnosa* is distinguished by something more than "pedunculis brevioribus et capitulis radiatis," as it has also a highly conical receptacle and no pappus.

PERITYLE Benth. The pappus, viz., the crown of squamellæ, which belongs to all the species of this genus and to no *Laphamia*, forms the best character for distinguishing these two genera. Mr. Bentham pro-

poses to transfer from *Perityle* the species which have subulate instead of linear style-appendages. But this separates plants of wholly similar aspect and structure, and would bring into *Perityle* the *Laphamia dissecta*, which has short and obtuse style-appendages. I do not find that the involucral scales are to any extent or with any uniformity wrapped around the outermost akenes. *Perityle Emoryi* and *P. nuda* (forms of one species), although referred by Bentham to *Laphamia*, have short and obtuse style-appendages in our specimens; but a plant which I cannot otherwise at all distinguish, collected on Carmen Island, in Lower California, by Dr. E. Palmer, in 1870, has them subulate and acute. As to the character "receptaculum convexum vel conicum," the receptacle was described and figured as flat in the original *Perityle*: in fact it is barely convex in some species, but strongly so in others.

WHITNEYA Gray. Since this genus was characterized, from scanty specimens, I have myself collected the plant, and have received from Drs. Bolander and Kellogg specimens with well-formed fruit. Upon these materials the genus is newly characterized for the Flora of California. The principal points of emendation are these: 1. The ligules become papery, almost as much so as in a *Zinnia*, and persist on the achenium, with which they are articulated indeed, but from which they are not readily separated: the 10 to 16 nerves are prominently decurrent down on the short tube of the ray. 2. The ovaries of the disk are all sterile, although the style-branches bear obvious stigmatic lines; and the disk-corollas appear equally to persist on the sterile achenia. 3. The rays mostly bear sterile filaments. 4. I do not verify Bentham's character of the inclusion of the ray-achenia in the scales of the involucre. They are concave close to the base, indeed, but not at all so as to embrace the achenium. The genus may be associated with

RIDDELLIA Nutt. The *Zinnia*-like persistence of the rays is not noted in the Genera Plantarum, except by the phrase "lamina rigidula." The rays do become more rigid than in

BAILEYA Gray. In this the persistent scarious rays want the tube, as is mostly the case in *Zinnia*. The affinity of these three genera (i.e. of *Riddellia*, *Baileya*, and *Whitneya*) now becomes manifest. They form a group in the *Helenioideæ* analogous to that of the *Zinneæ* in *Helianthoideæ*. In the Flora of California, now in preparation, I have accordingly formed of them the subtribe RIDDELLIEÆ.

BÆRIA and BURRIELIA. If the two genera are kept up in the manner proposed by Mr. Bentham, as seems on the whole advisable, the stress of the character of the latter should come rather upon the

very short and few rays and the slender receptacle, than upon the form of the appendages of the style. The difference is not great between those of *Burrielia leptalea* Gray, with slender subulate appendage abruptly contracted from a broad basal portion, and those of *Burrielia* now *Bæria platycarpha*, which are truncate-capitate, but flat, with short central cusp; and in other *Bæriæ* this cusp is represented by a more or less obvious, or sometimes evanescent, setiform point. *B. maritima* has short rays, indeed, but they are broad and flat, and the receptacle is broadly and obtusely conical. The species of *Bæria* are as below.*

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* BÆRIA Fisch. & Meyer, Benth. & Hook.

§ 1. Pappus semper nullus; achenia apice rotundata, areola epigyna parvula. Folia integerrima. (*Bæria* Fisch. & Meyer.)

1. B. CHRYSOSTOMA Fisch. & Meyer., cum var. MACRANTHA, *Burrielia chrysostoma* var. *macrantha* Gray in Bot. Whipp. — Varies from these largest to depauperate and slender forms, with rays and involucral scales reduced to 5 or 6.

§ 2. Pappus uniformis, ex aristis paleisve aristatis 2–7, raro nullus? Achenia apice truncata, areola epigyna lata. (*Burrieliæ* sp. DC. etc.)

* Folia integerrima.

2. B. GRACILIS. *Burrielia gracilis* DC. — Receptaculum angustissime conicum, acutissimum: pappus ex aristis (in radio 2–3, disco 4–5) basi angusta sensim paleaceo-dilatatis. — In some specimens the awns are scarcely dilated at base, in others the paleaceous portion is lanceolate or almost ovate-lanceolate.

3. B. TENERRIMA. *Burrielia tenerrima* DC. *B. parviflora* & *B. longifolia*? Nutt. — Receptaculum latiuscule conicum parum acutum: pappus ex aristis tenuibus 2–5 basi in paleam late ovatam subito dilatatis. — Both this and the foregoing occur in very depauperate forms, either of which may have been De Candolle's *Burrielia tenerrima*, but I take this to be it. As they are distinguishable only by the pappus, they perhaps run together.

* * Folia in eadem stirpe integerrima et tripartita: pedunculus sursum crassior: pappi paleæ 6–7, oblongo-ovatæ, aristæ æquilongæ.

4. B. PLATYCARPHA. *Burrielia platycarpha* Gray.

§ 3. DICHÆTA. Pappus biformis, nempe ex aristis 2–7 cum paleis multo brevioribus muticis interjectis, nunc in eadem spec. nullus. Achenia areola epigyna latiuscula. Folia saltem infima pinnatifida vel laciniata. (*Dichæta* Nutt.)

* Folia pleraque integerrima, lato-linearia: ligulæ breves.

5. B. MARITIMA. *Burrielia* (*Dichæta*) *maritima* Gray. Pappus ex aristis 3–5 validis et paleolis pluribus angustis laciniatis interpositis.

* * Folia nonnulla tri-pluripartita: ligulæ majores.

6. B. FREMONTII. *Dichæta Fremontii* Torr. *Burrielia Fremontii* Benth. Pl. Hartw.; forma epapposa, an semper? Folia angustissime linearia, nunc integer-

ACTINOLEPIS DC., Benth. In several specimens of *A. multicaulis* DC., collected by Professor Brewer, there is a pappus to the disk-flowers, like that of the ray. This confirms the propriety of referring to this genus Nuttall's *Ptilomeris*, which accords with it in what is well taken as the leading generic character, namely, the enclosure more or less of the ray-achenia in the at length concave or involute scales of the involucre. This, I find, is equally the case with two species, one of which (on account of its setiform anther-tips and the pappus) I had referred to *Burrielia*, as then characterized, and the other to *Bahia*, from which it differs only in the anther-tips, and, as I now perceive, in the inclusion of the ray-achenia. Both, indeed, have an obtusely conical receptacle, which would exclude them from *Bahia* as characterized in the Genera Plantarum; but this is also the case, to an equal degree, in one or two species of the *Eriophyllum* section of *Bahia*.

The receptacle varies so widely in *Actinolepis* as now constituted that it may take in another species with a flat receptacle, namely, *Burrielia nivea* of D. C. Eaton; but this has peculiar achenia and pappus, and may be the type of a distinct genus.

As revised for the Californian Flora the genus is arranged as below.*

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rima, nunc trisecta: pappus ex aristis sæpius 4 tenuibus, cum paleis 6–8 brevissimis lineari-oblongis integerrimis vel bifidis, nunc nullus.

7. B. ULIGINOSA. *Dichæta uliginosa* Nutt. Vegetior, foliis sæpissime pinnatifidis, rhachi lata: pappus ex aristis 2–3 paleaceo-subulatis et paleis 3–6 latissimis quadratis laciniato-fimbriatis, nunc plane nullus. —Var. TENELLA (*Dichæta tenella* Nutt.), forma tantum exigua, minus pinnatifida, ligulis involucrique squamis paucioribus.

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* ACTINOLEPIS DC., Benth.

§ 1. PTILOMERIS. *Bæriæ* § *Dichætæ* affinis: plantæ haud lanatæ, sæpissime glandulosæ; foliis oppositis pinnatipartitis, segmentis lineari-attenuatis; capitulis longius pedunculatis. Involucrum campanulatum vel hemisphæricum. Receptaculum alte acute conicum. Antheræ appendice oblonga superatæ. — *Ptilomeris* Nutt. *Hymenoxys* § *Oxypappus* Torr. & Gray.

* Glandulosa; ligulis 10–15 elongato-oblongis; involucri squamis oblongo-lanceolatis; receptaculo pl. m. pubescente. — Sequentes an species, an stirpes pappo solum diversæ?

1. A. CORONARIA. Pappo e paleis 10 (8–12) oblongo-lanceolatis in aristam productis, paucisve in radio nunc exaristatis. — *Ptilomeris coronaria* & *P. aristata* Nutt. *Shortia Californica* Nutt. in cat. hortul. *Hymenoxys Californica* Hook. Bot. Mag.; Torr. & Gray, Fl.

2. A. ANTHEMOIDES. Magis glandulosa; foliis tenuiter dissectis; capitulis

SCHKUHRIA Roth. To this genus *Bahia pedata* and *B. biternata* Gray, with annual root and costate pappus, are properly referred by

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parum minoribus; pappo nullo. — *Ptilomeris* (*Ptilopsis*) *anthemoides* Nutt. *Hymenoxys calva* Torr. & Gray.

3. A. MUTICA. Præcedenti simillima, nisi pappo e paleis 6–8 quadrato-oblongis apice eroso-lacinulatis muticis, paucisve raro aristulatis. — *Ptilomeris mutica* Nutt. *Hymenoxys* Torr. & Gray.

* * Subpubescens, vix glandulosa; ligulis brevioribus ovalibus 6–8; involucri squamis ovatis; receptaculo glabro.

4. A. TENELLA. Omnibus partibus minor; pappo e paleis 5–8 quadratis apice latissimo fimbriatis, paucisve nunc tenuiter aristulatis. — *Ptilomeris tenella* & *P. affinis* Nutt. Pl. Gamb.

§ 2. EUACTINOLEPIS. Floccoso-lanata; foliis plerisque alternis, paucilobatis vel integerrimis; ligulis pauciusculis obovatis. Involucrum angustum. Receptaculum aut convexum aut obtuse conicum. Pappus 8–15-paleatus vel squamellatus.

* Capitula parva sessilia vel folioso-bracteata; ligulis (flavis) 5 vel paucioribus; receptaculo tantum convexo; antheris appendice ovato-lanceolata superatis; pappo e squamellis angustis inæqualibus sæpius 15, vel fl. disci nullo.

5. A. MULTICAULIS DC. Specimens collected by Professor Brewer have pappus to the disk as well as ray-flowers.

* * Capitula majora pedunculata; ligulis 6–8; receptaculo obtuse conico; antheris appendice tenera fere setiformi (modo *Burrieliæ*) superatis; acheniis omnibus papposis.

6. A. WALLACEI. Albo-lanosissima; foliis obovatis spathulatisve apice nunc 3-lobatis; styli ramis cono subulato superatis; pappi paleis 8–10 brevibus obtusis muticis enerviis. — *Bahia Wallacei* Gray in Bot. Whippl. p. 49; forma normalis ligulis aureis. — Var. RUBELLA, ligulis roseo-purpureis albisve. *Bahia rubella* Gray in Bot. Mex. Bound. p. 95.

7 A. LANOSA. Albido-lanata; foliis linearibus sæpissime integerrimis; ligulis albis vel roseis; acheniis gracillimis; styli ramis obtusis vel tenuissime apiculatis; paleis pappi 8 vel 10 biformibus, 4 vel 5 subulatis in aristam attenuatis, alternis minoribus vel brevioribus exaristatis. — *Burrielia* (*Dichæta*) *lanosa* Gray in Bot. Whippl. p. 51. — In both these, and especially in the present species, the scales of the involucre each enclose a ray-achenium.

§ 3. EATONELLA. Floccoso-lanata, depressa; foliis (spathulatis integerrimis) plerisque alternis sed confertis; ligulis 8–9 parvulis. Receptaculum planum, callosum. Antheræ appendice latiuscula obtusa superatæ. Achenia linearia, compressa, faciebus planis nitidis, marginibus callosis villosissimis: pappus e paleis hyalinis 2 ovatis in aristam productis.

8. A. NIVEA. *Burrielia nivea* D.C. Eaton, in S. Watson, Bot. King, p. 174, t. 18. — Achenia of the ray partly enclosed in the concave scales of the involucre.

Bentham, as also *Achyropappus* HBK. The North American species are characterized below.* I have to add a peculiar perennial species.

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* § 1. SCHKUHRIA VERA. Capitulum pauciflorum: involucrum turbinatum vel in sicco pyramidatum, e squamis 4–5 obovatis apice sphacelato coloratis: ligulæ 1–2 brevissimæ imperfectæ: achenia obpyramidato-tetragona. Folia vel segmenta fere filiformia.

1. S. HOPKIRKIA Gray, Pl. Wright, 2, p. 94. Ramosissima; capitulis 3–4-floris; ligula unica nunc nulla; acheniis ad angulos villosissimis faciebus trinervatis; pappi paleis 8 conformibus ovatis corollam æquantibus nervo valido excurrente aristellatis. — *Hopkirkia anthemoidea* DC. — Southern borders of Arizona, C. Wright, and Mexico.

2. S. WRIGHTII Gray, l. c. Gracilis; capitulis 3–5-floris; ligula unica; acheniis præcedentis sed minus crassis; pappi paleis 8 conformibus obovatis muticis basi tantum incrassatis corolla paullo brevioribus. — Southern borders of Arizona, near Santa Cruz, Sonora.

§ 2. ACHYROPAPPUS. Capitulum pluri–multiflorum: involucrum sæpius hemisphæricum: ligulæ 5–12 exsertæ, raro nullæ: corolla limbo magis ampliato. (Achenia in nostris attenuata.)

* Ramosissima, gracillima, glabella; foliorum segmentis angustissime linearibus integerrimis: pappi paleæ 8 obovatæ, muticæ, præter basim incrassatam opacam enerviæ.

3. S. NEO-MEXICANA Gray, Pl. Fendl. p. 96. Spithamæa; pedunculis breviusculis subpaniculatis; ligulis nullis; pappo corollam subæquante. — Santa Fé, &c., New Mexico.

4. S. BIGELOVII. Ultrapedalis; foliis caulinis plerisque oppositis; pedunculis elongatis filiformibus; ligulis 8–9 oblongis; pappo tubo corollæ disci breviore. — *Bahia* (*Achyropappus*) *Bigelovii* Gray, in Bot. Mex. Bound. p. 96.

* * Ramosa, humilis; foliis plerisque oppositis pinnato-3–5-partitis, segmentis linearibus: pappi paleæ 8–9 lanceolatæ, costa valida percursæ: achenia vix angulata.

5. S. WOODHOUSEI. *Achyropappus Woodhousei* Gray, Proc. Am. Acad. 6, p. 546. — New Mexico, Dr. Woodhouse.

* * * Pedalis ad bipedalem, cinereo-puberula; foliis alternis pedati- vel palmatisectis; capitulis in caule apice nudo corymbosis: pappus e paleis 10–14.

6. S. PEDATA. Foliorum segmentis obovatis vel cuneato-oblongis; pappi paleis obovatis retusis, costa valida infra apicem evanida. — *Bahia pedata* Gray, Pl. Wright, 1, p. 123. — Western borders of Texas, &c.

7. S. BITERNATA. Foliorum segmentis linearibus; pappi paleis lineari-lanceolatis costa excurrente aristatis achenio subæquilongis, vel in fl. extimis latioribus muticis. — *Bahia biternata* Gray, Pl. Wright, 2, p. 95. — New Mexico.

§ 3. PLATYSCHKUHRIA. Capitulum floresque *Achyropappi*, habitu proprio, radice perenni etc. ut in char. specif.

8. S. INTEGRIFOLIA. Cinereo-puberula, nunc glabrata; caulibus floriferis e caudice multicipiti erectis spithamæis sæpius scapiformibus basi tantum foliosis

Hymenothrix Gray, Pl. Fendl. p. 102, & Pl. Wright, 2, p. 97. By the admission of the above-mentioned perennial species into *Schkuhria*, the difference between that genus and the present is lessened; but still this should hold, *H. Wrightii* being especially peculiar, and the original *H. Wislizeni* nearer to it than to any thing else. It should be noted that the flowers of *H. Wrightii* are not yellow, as in the other, but pale purple or flesh-color.

Blennosperma Less. This genus seems to have no very evident relationship to those with which it is associated in the Genera Plantarum. In the character no mention is made of three peculiarities: 1. the completely sessile ligule; 2. the inner row of pistillate apetalous flowers, which appear to be constant in the Californian species; and 3. the powdery papillæ of the achenium and their development of delicate threads when wetted, forming a gelatinous mass, as in *Crocidium* and other Senecioneous Compositæ, and which indicate an affinity in that quarter.

Chænactis DC. well includes *Acarphæa* Gray. Few if any of the species have perennial roots. *C. carphoclinia* Gray is an anomaly in the tribe on account of the paleæ of the receptacle.

Nicolletia Gray. This (not *Nicolettia*) is the proper orthography of the name of this genus, which was dedicated to the memory of T. N. Nicollet, under whom Fremont performed his first service in survey and exploration.

Dysodia Cav. Although the pappus generally consists of only 10

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apice corymboso-1–5-cephalis; foliis alternis crassiusculis coriaceis ovalibus nunc oblongis leviter trinerviis integerrimis in petiolum gracile subito angustatis; involucri hemisphærici squamis 10–14 oblongo-lanceolatis acutis disco brevioribus; ligulis 6–9 exsertis oblongis sæpe 3-dentatis; acheniis lineari-cuneatis 4-gonis; pappi paleis lineari-lanceolatis hyalinis costa valida excurrente vel procurrente subaristatis, vel mucronatis vel fl. exteriorum oblongis omnino muticis. — Denudated high plains and valleys in the Rocky Mountains of Wyoming, Valley of Wind River, &c.; Dr. Parry, coll. 1873, no. 150.

Var. oblongifolia, minor; caule sat folioso; foliis lanceolato-oblongis; floribus in capitulo angustiori minus numerosis. — Hillsides in the valley of San Juan (Utah or New Mexico), Newberry in McComb's expedition. Head in specimen of this form (which has been for several years in the herbarium) barely 5 lines high and rather narrow; but in Dr. Parry's plant half an inch high and much broader. In the latter the flowering stems are usually scapiform, with some small bracts in place of leaves; the blade of the tufted radical leaves an inch to an inch and a half long, and about half as wide. Flowers yellow: disk-corolla with broadly funnel-form 5-lobed limb from a narrow tube. Style-branches capitate-truncate, with a short conical apiculation.

paleæ, Bentham's *D. anthemidifolia* of Lower California is said to have about 20. The following I had at first taken for a variety of *D. porophylloides* Gray, Pl. Thurb.

Dysodia Cooperi. Scabro-puberulum; foliis (caulinis ignotis) ramealibus lanceolatis crassiusculis sessilibus inciso-dentatis basim versus utrinque in segmentum lanceolato-subulatum stipulæforme partitis, superioribus in bracteas subulatas diminutis; capitulo pollicari bracteis calyculiformibus numerosis in squamas involucri lineari-subulatas sensim acuminatas transeuntibus; ligulis "purpureis" lineari-oblongis breviter exsertis; acheniis puberulo-hirtellis, pappi paleis circiter 9-setosis. — South-eastern borders of California, on the eastern side of Providence Mountains, Dr. J. G. Cooper.

Helenium Linn. I cannot at all accept the idea that *Amblyolepis* DC. belongs to this genus. The habit of the plant, the clasping leaves wholly destitute of impressed punctures (and with somewhat the odor of Melilotus in drying), the long bristly hairs, and the peduncules nodding before anthesis in a Cichoriaceous fashion, are too peculiar: so is the abrupt change from the foliaceous outer series of involucral scales to inner scarious ones, as hyaline as the paleæ of the pappus, and hardly larger. Then the disk-corollas, instead of the very short tube and cylindraceous limb with very short and blunt glandular teeth of *Helenium*, have a slender tube and a cyathiform or funnel-form 5-cleft limb; the lobes deltoid-lanceolate, acute, and glabrous. The achenia with 10 very thick ribs are somewhat peculiar. But the rays with ligule destitute of tube are as in *Helenium*. The tube to the disk-corolla is well developed in two anomalous *Helenia*, *H. Hoopesii* and the *Actinea integrifolia* HBK., which Bentham associates with it. Perhaps it would not be amiss to restore the genus *Oxylepis* for these.

Leptopoda Nutt. is well united to *Helenium*. But the union clearly carries with it *Hecubæa*, i.e. DeCandolle's *Hecubæa*, whatever that of Bentham (or Bourgeau's plant) may be. My reference of Ghiesbreght's plant (in Proc. Am. Acad. 7, p. 359) to *Hecubæa* DC. was based on a comparison with an imperfect original specimen; and I am still disposed to think that the species are not distinct. However this be, it may be affirmed of both that the characters — "involucrum late turbinatum, bracteis . . . basi connatis: receptaculum elevato-conicum," and "receptaculo valde elevato" — do not apply. The receptacle, however, is not "planiusculum," as De Candolle describes it, but in Ghiesbreght's plant rather more than hemispherical. The rays in the latter sometimes possess and sometimes want the style. I doubt if they are truly fertile in either.

A little scarious chaff on the receptacle is not uncommon in *H. nudiflorum* and I believe in *H. autumnale* also. An arrangement of the known species is subjoined.*

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* HELENIUM Linn.

§ 1. EUHELENIUM. Ligulæ fertiles, rarissime imperfecte styliferæ vel neutræ, sæpius nutantes. Corollæ disci tubo proprio brevissimo vel subnullo. Pappi paleæ haud dissectæ. Caules plerumque ramosi.

* Annua vel biennia; capitulis parvulis nunc mediocribus; corollis disci in eadem stirpe 4–5-dentatis.

+ Pappus brevissimus, e paleis rotundatis ecostatis muticis.

1. H. QUADRIDENTATUM Labill. Foliis inferioribus sæpius laciniato-pinnatifidis; capitulo elongato, nempe disco oblongo-ovato ligulis plerumque duplo longiore; receptaculo oblongo-cylindraceo. — S. Atlantic States to Mexico.

2. H. MICROCEPHALUM DC. Gracile; foliis angustis, radicalibus pinnatifidis; capitulis corymbosis vel paniculatis parvis; disco globoso ligulas paullo parumve superante; receptaculo ovato vel subgloboso. — *H. heterophyllum* DC. Prodr., quoad stirp. Berland. no. 2118. *H. Texanum* Buckley. — Var. BICOLOR Torr. & Gray. *H. elegans* DC. l. c. — Texas and adjacent parts of Mexico, to Tantoyuca, Ervendberg. Var. *bicolor* has a more depressed globular head, and the receptacle approaching hemispherical instead of ovate; but it is similar in some specimens of the ordinary form. De Candolle's *H. heterophyllum* is, at least mainly, represented in his herbarium by Berlandier's no. 2118, from Reynosa, Tamaulipas, which is the same as his no. 1429, from Laredo, Texas; but the character of the pappus in the Prodromus is inapplicable to this species.

3. H. AMPHIBOLUM. Major; foliis radicalibus ignotis, superioribus remote denticulatis vel integerrimis; capitulis sparsis longius pedunculatis; disco globoso subdepresso ligulis rite evolutis breviore; receptaculo ultra-hemisphærico. — *H. Mexicanum* DC. Prodr. 5, p. 666 (ex char. pappi, etc.), non HBK. — Mexico. State of Chihuahua, near Monterey, Berlandier (no. 145 coll. anno 1828), Dr. Gregg; and near Saltillo, Dr. Gregg. — Head nearly twice the size of the preceding species; the rays from fully half to at least a third of an inch long. Receptacle 2 lines high and almost 3 lines wide, forming nearly two-thirds of a sphere.

+ + Pappus mediocris, e paleis obtusis muticis, costa vix ulla: receptaculum ovoideo-conicum acutiusculum.

4. H. OOCLINIUM. Tenuiter puberulum; caule corymboso-ramoso; foliis lineari-lanceolatis remote denticulatis (imis ignotis); ligulis pauciusculis disco ovato-globoso dimidio brevioribus; pappi paleis corolla disci $\frac{1}{3}$–$\frac{2}{3}$ brevioribus oblongo-ovatis achenio subæquilongis. — State of Chihuahua, Mexico, in the Nazas Valley, Bolson di Mapimi, Dr. Gregg. — Herb doubtless 2 feet high, and with the aspect of the preceding, except that the rays are shorter (2 or 3 lines long), and the disk (often half an inch high and fuscous) inclined to ovoid. The well-developed receptacle is 4 lines high, and ovate-conical. This may be De Candolle's *H. heterophyllum* in part, as that is said to have a "capitulum ovato-globosum" and pappus twice or thrice shorter than the corolla, but this

TANACETUM Linn. On account of the corymbose heads and broad abrupt summit of the achenium, the following must be transferred to this genus:—

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in the present plant is not "obtusiusculis breviter aristatis." I do not find it among Berlandier's *reliquiæ* here; and that species, as already stated, was founded mainly on Berlandier's no. 2118, which is *H. microcephalum*.

+ + + Pappus mediocris vel majusculus, e paleis latis costa pl. m. perspicua percursis mucronatis aristatis vel acuminatis; receptaculum semi- vel subglobosum.

++ Folia lanceolata seu lanceolato-linearia, ima oblanceolata seu oblongo-spathulata: discus globosus.

5. H. MEXICANUM HBK. Foliis subintegerrimis; capitulis corymbosis breviuscule pedunculatis; ligulis disco brevioribus; pappi paleis ovatis tenuiter apiculatis seu aristellatis costa subevanida percursis corolla 2–3-plo brevioribus. —*H. varium* Schrader; DC. Prodr. l. c.? Mexico.—Kunth does not mention the size of the pappus, either absolutely or relatively to the corolla; but in his specimen it is actually almost half the length of the disk-corolla; so that De Candolle's plant with pappus only one-fifth of the length of the disk-corolla is something else; and his as well as Schrader's *H. varium* is probably the true *H. Mexicanum*,—to which belong Andrieux's no. 190, and Hartweg's 130.

6. H. LACINIATUM. Humile, cinereo-puberulum; foliis sæpius pinnatifido-dentatis vel incisis; capitulis sparsis longe pedunculatis; ligulis disco dimidio brevioribus; pappi paleis ovatis in aristam corolla paullo breviorem subito angustatis.—California (probably on the southeastern borders), Coulter, no. 356, 358. Yaqui River, near the eastern side of the Gulf of California, in Sonora, Dr. E. Palmer.

7. H. PUBERULUM DC. Elatum, paniculato-ramosum; foliis integerrimis; capitulis longe pedunculatis; ligulis disco dimidio vel multo brevioribus sæpe inconspicuis; pappi paleis ovatis breviter aristatis corolla 3–4-plo brevioribus.

++ ++ Folia angustissime linearia, innumera: discus globosus, ligulis sat magnis superatus.

8. H. TENUIFOLIUM Nutt.—Mississippi to Texas. Clearly the root is not perennial. The pappus is produced into long and capillary awns.

* * Perennia, surculis radicalibus biennibus renovata: pappi paleæ integræ vel eroso-denticulatæ, pl. m. acuminato-aristatæ: ligulæ discum globosum vel subdepressum æquantes sæpiusve superantes.

+ Neutri, rarius styliferæ steriles: receptaculum ovoideum.

9. H. NUDIFLORUM Nutt. *H. nudiflorum, micranthum*, et *parviflorum* Nutt. in Trans. Am. Phil. Soc. n. ser. 7, p. 384, 385. *H. Seminariense* Featherman, in Louisiana Geol. Rep. *Leptopoda brachypoda* Torr. & Gray.—Var. PURPUREA, *H. atropurpureum* Kunth, Ind. Sem. Berd. 1845, p. 21.—Delaware? to Illinois and Texas. Varies with flowers all yellow, or the disk brown purple, or the rays partly or almost wholly brown purple. *H. parviflorum* Nutt. from Georgia, in my authentic specimen, has wholly neutral rays, and is manifestly of this spe-

TANACETUM POTENTILLOIDES. *Artemisia potentilloides* Gray, Proc. Am. Acad. 6, p. 551. The hirsute receptacle is peculiar. The

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cies. Dr. Engelmann communicated styliferous specimens which seem to be hybrids between this species and *H. autumnale*.

+- +- Ligulæ styliferæ fertiles: receptaculum semi-½-globosum.

++ Capitula mediocria vel majuscula: pappi paleæ corolla breviores.

10. H. AUTUMNALE Linn. Caule ad apicem usque folioso plerumque corymboso-polycephalo; foliis lato-lanceolatis nunc serratis; pedunculis sæpius brevibus.— *H. grandiflorum* & *H. montanum* Nutt. l. c. — Atlantic States and Canada to the Pacific.

11. H. BIGELOVII Gray, Bot. Whipp. p. (107) 51. Caule gracili sæpius simplici monocephalo; pedunculo elongato; foliis a linearibus ad lato-lanceolata integerrimis; capitulo sæpius majore. — Variat caule ramoso ligulis brevioribus. — California.

++ ++ Capitula magna, disco primum hemisphærico pollicem diametro, ligulis pollicaribus: pappi paleæ aristatæ corollam disci subæquantes: pedunculi longi validi, sæpius fistulosi, sub capitulo turbinato-incrassati ut in *Leptopoda*.

12. H. BOLANDERI Gray in Proc. Am. Acad. 7, p. 358. — Northern part of California along the coast, Bolander. — The small paleæ of the pappus are mostly sparingly laciniate-toothed, the teeth more or less prolonged and bristle-shaped.

§ 2. LEPTOPODA. (*Leptopoda* Nutt.) Ligulæ numerosæ neutræ. Pappi paleæ sæpe laceratæ vel fimbriatæ, costa nulla seu evanida. Caulis simplex e radice perenni, virgatus, apice plerumque longe nudo monocephalus. Cæt. *Euhelenii*.

* Receptaculum ovato-conicum: discus demum subglobosus: folia plerumque integerrima, fere glabra, pl. m. elongata, lanceolata, superiora linearia: achenia ad angulos hirsuta.

13. H. FIMBRIATUM Gray. Bi-tripedale, gracile; capitulo sat magno (disco ultra-semipollicari); pappi paleis ultra medium in setas plurimas capillares solutis. — Gray in E. Hall, List, Pl. Tex. no. 360. *Gaillardia fimbriata* Michx. *Leptopoda fimbriata* Torr. & Gray, Fl. 2, p. 387. — Florida to Texas. Rays three-fourths of an inch long. Disk in fruit 3 or 4 lines high, foveolate with the borders of the areolæ corneous, as in *H. vernale*.

14. H. CURTISII. Præcedenti simile; capitulo minore; pappi paleis lato-obovatis subintegerrimis corolla disci fere triplo brevioribus. — *Leptopoda brevifolia* var. Torr. & Gray l. c. *L. integrifolia* M. A. Curtis, Mss. — Near Raleigh, North Carolina, M. A. Curtis.

* * Receptaculum vix hemisphæricum: discus convexus.

+- Achenia glaberrima, immaturis resinoso-atomifera: pappi paleæ pl. m. laceratæ, setulæ haud raro aristellatæ.

15. H. NUTTALLII. — *Leptopoda Helenium* & *L. denticulata* Nutt. *L. decurrens* Macbride in Ell. — South Carolina to Florida and Louisiana. Foliage nearly as in *H. fimbriatum;* the stem less tall. — Var. INCISUM? *Leptopoda incisa* Torr. &

achenium is of thin and delicate texture, utricular, and it swells up into a jelly-like mass in water: under the microscope some of its cells are found to contain spiral threads.

ARTEMISIA Linn. The technical distinctions between this genus and *Tanacetum* are evanescent. As to the ribs of the akene, these are five and well marked in several species, among which are *A. tridentata* and *A. Norvegica.* And *A. Californica* has not only these, but the broad epigynous disk (more or less obvious in other species) is bordered by an obsolete pappus. On the other hand, the ribs disappear in some genuine *Tanaceta*, and the disk is very small in the turgid ripe achenia of *T. Sibiricum.* The habit and inflorescence furnish the more obvious distinctions.

Gray, l. c. This I do not possess. It was described from a specimen in Dr. Torrey's herbarium.

+- +- Achenia secus angulos hirsuta vel hirtella: folia breviora, crassiuscula.

16. H. VERNALE Nutt. Glabellum vel tomentuloso- vel viscidulo-pubescens; foliis nunc integerrimis nunc rariter dentatis vel incisis; pappi paleis obovatis spathulatisve apice lacerato-denticulatis vel erosis corolla dimidio (rarius triplo) brevioribus. — *Leptopoda puberula* Macbride in Ell. *L. pinnatifida* Nutt. — North Carolina to Florida.

17. H. BREVIFOLIUM. Fere glabrum; foliis brevibus plerisque spathulatis integerrimis; pappi paleis obovatis subintegerrimis; corollis disci apice atropurpurascentibus. — *Leptopoda brevifolia* Nutt. in Trans. Amer. Phil. Soc. 7, p. 378; Torr. & Gray, l. c. excl. var. — Georgia to Alabama.

§ 3. HECUBÆA. (*Hecubæa* DC.) Ligulæ sæpius fœmineæ (vix fertiles ?). Pappus nullus vel minutissimus coroniformi-squamellatus. Cætera *Leptopodæ*.

18. H. SCORZONERÆFOLIUM Gray, Proc. Am. Acad. 7, p. 359. *Hecubæa scorzoneræfolia* DC. Prodr. 6, p. 665, Deless, Ic. Sel. 4, t. 43. — Mexico, Alaman.

Var. GHIESBREGHTII Gray, l. c. — Chiapas, Mexico, Ghiesbreght, no. 118, 527, new distribution. — See remarks at the head of this article.

§ 4. OXYLEPIS. (*Oxylepis* Benth. Pl. Hartw.) Ligulæ numerosæ, lineari-cuneatæ, fertiles. Corollæ disci tubo proprio sat longo instructæ! Pappi paleæ subulatæ, enerviæ, integerrimæ. Perennes, andinæ, megacephalæ, habitu insigni.

19. H. HOOPESII Gray, in Proc. Acad. Nat. Sci. Philad. 1863, p. 65; Eaton in S. Watson, Bot. King, p. 175. — Rocky Mountains in Colorado Territory to the Sierra Nevada in California.

20. H. LANATUM. *Actinea integrifolia* HBK. Nov. Gen. & Spec. 4, p. 297, t. 410. *Oxylepis lanata* Benth. Pl. Hartw. p. 87. Mexican Andes. — I have no specimen of this, which Mr. Bentham finds is a near relative of *H. Hoopesii.* The receptacle must be much flatter, and the rays (about 40) much more numerous, as shown in Kunth's figure: the tube of the disk-corolla is represented as long as the limb. It is similar but shorter in the North American species.

CROCIDIUM Hook. The broad and flat branches of the style are decidedly Asterideous, as Mr. Bentham remarks; and the genus might be better placed there than among the *Senecioneæ*, except for the thread- and mucilage-bearing papillæ of the akenes, which are common in *Senecio*. In this respect, as in the shape of the achenium, and the broad and flat style-branches, no less than in the involucre and habit, it much resembles another genus of uncertain affinity, namely, *Blennosperma*, as was noticed long ago in the Flora of North America. I find that I once inadvertently mistook the latter for *Crocidium*, whence that plant was, in the Botany of the Mexican Boundary, said to have been collected in California. It has not yet been seen south of Oregon. The small cauline leaves, described as "omnia integra" in the Genera Plantarum, are mostly 3-cleft, as in Hooker's plate.

BARTLETTIA Gray cannot be nearly allied to *Crocidium*, having none of the peculiar characters of that genus.

PSATHYROTES Gray. The affinity of this genus with the two following seems to me unmistakable and close. Rather than to distribute them under different tribes, it might be better to take *Trichoptilium* also into the *Senecioneæ*, accounting the bristles of the pappus to be united at base to form the scales. But technically the latter genus has the character of the *Helenioideæ*. In the yet unpublished Flora of California I have ventured to unite with *Psathyrotes*, under the name of

PSATHYROTES (PEUCEPHYLLUM) SCHOTTII, the *Peucephyllum Schottii* Gray in Bot. Mex. Bound. p. 74. I had referred this plant to the *Eupatoriaceæ*, on account of the styles and the impressed-punctate leaves, supposing that the flowers were not truly yellow. Bentham recognized an affinity with his *Luina*, which has the same inappendiculate style. The flowers in other respects are apparently just those of *Psathyrotes;* and the style-branches of *P. scaposa*, although somewhat hispid, are equally destitute of any tip.

LUINA Benth. Notwithstanding its Inuloid style-branches, this genus is most related to *Tetradymia*, and indeed might almost be regarded as a section of it. Now that the long hairs of the achenium of the latter are known to be inconstant, *Luina* is distinguished from it only by the total absence of appendage or tip to the style-branches, and the less deeply cleft corolla, the lobes of which are much shorter than the tubular-funnelform throat. The midnerve of the corolla-lobes is equally apparent in *Luina*, and the anthers are soon completely exserted. A form seemingly of the original species (*Luina hypoleuca*, var. *Californica*) has been collected on the coast range of California

behind Santa Cruz (also farther north), in which the lobes of the corolla are shorter than in Dr. Lyall's specimens.

TETRADYMIA DC. The style-branches of this well-marked genus seem never to be exactly "truncate and penicillate," but rather as figured in Delessert's Icones, with more or less of a conical tip, the base of the cone with some penicillation: occasionally the cone in *T. canescens* is more prominent, acute, and beset with a few stiff bristles. This is observed in some of the numerous specimens which have wholly glabrous ovaries. As the villosity of the akenes is not of generic or even of specific value, and the style-branches are somewhat variable, I am the more disposed to append to *Tetradymia* a plant of peculiar aspect, with twice as many flowers in the head as occur in *T. spinosa*, and with the involucre multibracteolate, so as to appear much imbricated. The acutish style-branches are peculiar (but not quite Asteroid): otherwise the flowers wholly accord with *Tetradymia*. The plant in view is

T. (LEPIDOSPARTON) SQUAMATA. *Linosyris squamata* Gray, Proc. Am. Acad. 8, p. 290. *Carphephorus junceus* Durand, in Pacif. R. R. Expl. 5, p. 8, non Benth.

RAILLARDELLA. I willingly adopt from Mr. Bentham the entire separation from *Raillardia* of these two interesting Californian species, *R. argentea* and *R. scaposa*. The scales of the involucre appear to be strictly in one series, and their edges are lightly united to the middle, although at length separating or separable. From the size, rigidity, and slight flattening of the bristles of the pappus, I still incline to refer *Raillardia* and *Raillardella* to the *Helenioideæ;* and *Dubautia*, although with paleaceous receptacle, is a manifest ally.

ARCTIUM Linn. Without raising any general question as to the recognition of Tournefortian genera when superseded by Linnæus, and where the Linnæan name has continued to prevail, I do not well see the necessity of reviving at the present day the Linnæan name *Arctium* (which included a Thistle as well as the Burdocks), after it has given way to *Lappa* Tourn., all the way from Jussieu down to De Candolle and Fries.

CNICUS Linn. For the reasons assigned by Mr. Bentham, and especially because he has done so in the new Genera Plantarum, it is best to adopt for the present genus this Linnæan rather than the Tournefortian name *Cirsium*. A revision of the North American species will be attempted in a separate article.

MICROSERIS Don. It is unfortunate, but inevitable, that this name should supersede the happier one of *Calais* DC., under which most of

the species have been described; but, as Bentham shows, *Microseris* is identical with *Eucalais*, except, I would add, in the number of the pappus-paleæ. — From it, however, Mr. Bentham distinguishes *Scorzonella* Nutt., even placing it in another subtribe. In revising these plants for the Californian flora, I find myself unable to adopt this conclusion. The basal callosity of the achenium, hollowed at the insertion, is shared by *Microseris* proper throughout. As to the remaining character, that of the graduated imbrication of the scales of the involucre, there is a transition (as also in the pappus) through *M. sylvatica* to the section *Ptilophora*, and through *M. Parryi* to the other sections. And *M. aphantocarpha*, with all the other characters of *Eucalais*, has the pappus-scale more obsolete than in any form of *M. laciniata*, the long bristle being undilated, except at its very insertion. The species may be disposed under five sections, as follows.*

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* MICROSERIS Don, Benth. & Hook.

§ 1. PTILOPHORA. Pappi aristæ (14–22) albo-plumosæ: achenia nec apice vix inferne attenuata, teretia: involucrum calyculatum vel imbricatum. Biennes, radicibus fusiformibus. — *Ptilophora* Gray, Pl. Fendl. p. 112. *Calais* § *Ptilophora* Gray, in Bot. Whipp.

1. M. NUTANS. *Scorzonella* (*Crepis* Geyer) *nutans* Hook. *Calais nutans* Gray, l. c. *Stephanomeria intermedia* Kellogg. — Gracilis; involucrum fere biseriale, squamis exterioribus brevibus calyculum efficientibus.

2. M. MAJOR. *Calais* (*Ptilophora*) *major* Gray, l. c. cum syn. *Calais gracililoba* Kellogg in Proc. Calif. Acad. 5, p. 40, forma laciniato-pinnatifida. — Involucrum magis imbricatum triseriatum.

§ 2. SCORZONELLA. Pappi aristæ (8–10, raro pauciores) aut subplumosæ sordidæ, aut nudæ: achenia nec apice parum basi attenuata: involucrum imbricatum, squamis exterioribus gradatim brevioribus. Biennes, radice fusiformi. — *Scorzonella* Nutt. *Calais* § *Scorzonella* & *Anacalais* Gray, in Bot. Whipp. *Scorzonella* Benth. & Hook. Gen. Pl. 2, p. 533.

* Achenia gracilia *Ptilophoræ*: pappus subplumosus vel barbellatus. (§ *Anacalais* Gray.)

3. M. SYLVATICA. *Scorzonella sylvatica* Benth. Pl. Hartw. *Calais* (*Anacalais*) *sylvatica* Gray, in Bot. Whipp. l. c.

Var. STILLMANI: squamis involucri e basi angustiore sursum sensim attenuatis; pappi aristis (quandoque) minus barbellatis. — *Calais sylvatica*, forma, Gray in Bot. Whipp. l. c.

* * Achenia parum breviora, nunc 4–5-angulata, nunc teretia gracilia: aristæ pappi tenuiter denticulatæ vel scabræ.

+ Involucri squamæ longius acuminatæ: pappus e paleis 8–10 parvis arista prælonga capillari superatis: ligulæ elongatæ. Caulescentes vel subcaulescentes.

GLYPTOPLEURA Eaton. To the characters of this curious little genus, as made known by Eaton and by Bentham, may here be added

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4. M. LACINIATA. *Hymenonema ? laciniatum* Hook. *Scorzonella laciniata* Nutt. *Calais* (*Scorzonella*) *laciniata* Gray, l. c., cum

Var. PROCERA. *Calais* (*Scorzonella*) *glauca, procera* Gray, Proc. Am. Acad. 7, p. 364. *Hymenonema ? glaucum* Hook., forma minor.

5. M. LEPTOSEPALA. *Scorzonella leptosepala* Nutt. *Calais Bolanderi* Gray Proc. Am. Acad. 7, p. 365. *Calais laciniata* Gray, l. c. 8, p. 392; pl. coll. Hall, 318. — The narrower and gradually tapering scales of the involucre, as well as the smaller and mostly fewer-flowered heads, appear well to distinguish this species, which was indicated by Nuttall.

+ + Involucri squamæ omnes obtusiusculæ: pappus e paleis 5 bifidis arista e sinu exserente dimidio triplove brevioribus constans: ligulæ breviusculæ. Acaulis, scapis simplicissimis nudis.

6. M. PARRYI. *Calais Parryi* Gray in Bot. Whipp. & Bot. Mex. Bound. p. 104. — Akenes unknown, but probably beakless. The species was referred to *Calocalais*, on account of the pappus.

§ 3. EUMICROSERIS. Pappus e paleis aristatis 10 vel pluribus: cæt. *Eucalais*. Species 2 australes.

7. M. PYGMÆA Don. Annua, radice exili. — Chili.

8. M. FORSTERI Hook. f. Biennis, radicibus fusiformibus. — New Zealand and Australia.

§ 4. EUCALAIS. Pappus haud plumosus, sordidus, e paleis aristisve 5, raro paucioribus: achenia sæpissime breviuscula, ab apice lato truncato vel infra medium deorsum angustata: involucrum duplex, exterius breve calyculatum. Annuæ, acaules, radice exili, scapis simplicissimis nudis. — *Calais* § *Eucalais* DC.

* *Aphantocarpheæ*, nempe aristis pappi fragilibus nudis ima basi tantum dilatatis.

9. M. APHANTOCARPHA. *Calais aphantocarpha* Gray in Proc. Am. Acad. 6, p. 552.

Var. TENELLA. Forma pusilla, pappo 2–5-mero deciduo nunc evanido. *Calais* (*Aphanocalais*) *tenella* Gray in Bot. Whipp. p. 57, 58, t. 17. — Evidently this is a depauperate state of the species which I later described as *Calais aphantocarpha*. It is so large and tall as to render the older specific name inappropriate, so that in the transference I prefer the later name for the species. The slight contraction of the very summit of the achenium in the *C. tenella* does not seem to be wholly constant, nor of specific value.

* * *Eucarpheæ*, nempe paleis pappi sat magnis,

+ Ovato-lanceolatis ovatisve in aristam pl. m. acuminatis.

10. M. BIGELOVII. Acheniis brevibus (lin. 2 longis) subturbinatis sub apice non constrictis; pappi paleis ovato-lanceolatis extus tantum scabrulis in aristam gracilem sensim productis. — *Calais Bigelovii* Gray, in Bot. Whippl. p. 57, t. 17. *C. Douglasii* Gray, Bot. Whipp. l. c. (forma paleis pappi fere lanceolatis) &

that the scales of the involucre are united at base for nearly one-third of their length (as may best be seen from within), and that the stout

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Bot. Mex. Bound. p. 164. Apparently a common species in the neighborhood of San Francisco; wherefore it is singular that neither Douglas nor Nuttall collected it.

11. M. Douglasii. Acheniis gracilioribus fusiformibus (sæpe lin. 3½ longis); pappi paleis ovato-oblongis ovatisve extus villosis apice in aristam sat validam breviter attenuatis. — *Calais Douglasii* DC. Prodr. 7, p. 85; Hook. & Arn. Bot. Beech. p. 361. Collected, as far as I know, only by Douglas. Characterized from his specimens in the Kew herbarium (herb. Hook. and herb. Benth.). According to my notes, only some achenia are in De Candolle's herbarium, and there is no mention in them, any more than in De Candolle's Prodromus, of the copious villosity of the paleæ of the pappus, which is described by Hooker and Arnott, and could hardly be overlooked in their specimens. This may sometimes be wanting, as in the following species, to which *M. Douglasii* also approaches in the texture and form of the paleæ. [From observations communicated by Dr. Müller, the Curator of De Candolle's herbarium, it appears that the plant described in the Prodromus is the same as that in the Kew herbarium, perhaps with the paleæ of the pappus rather wider.] But the slender and truly fusiform achenia, tapering almost as much to the summit as to the base (nearly as in *Calocalais*), seems well to distinguish it both from the preceding and the following species. Its rediscovery is very desirable.

+ + Orbiculatis seu latissime ovatis subito aristatis: achenia brevia, valida, sub apice haud vel paullulum constricta.

12. M. cyclocarpha. Pappi aristis gracilibus palea sua 2–3-plo longioribus. — *Calais cyclocarpha* Gray in Bot. Whipp. l. c. t. 18. — Paleæ of the pappus usually glabrous or nearly so, but occasionally bearing a few long villous hairs on the back, so as to connect to this species the

Var. eriocarpha: pappi paleis extus sericeo-villosis arista vix dimidio brevioribus. — *Calais eriocarpha* Gray, Proc. Am. Acad. 6, p. 552.

13. M. platycarpha. Pappi aristis palea sua 2–3-plo brevioribus. — *Calais platycarpha* Gray in Bot. Whipp. & Bot. Mex. Bound. l. c. — Of this only Dr. Parry's original specimen is yet known. The young achenia do not show the slight neck of the preceding species.

§ 5. Calocalais. Pappus haud plumosus, sæpissime 5-paleaceus: achenia gracilia, fusiformia, sursum sensim nunc rostratim attenuata: involucrum subduplex, squamis exterioribus paucis inæqualibus, omnibus lanceolatis. Subcaulescentes, pedunculis scapiformibus simplicissimis, ligulis abbreviatis pallidis? — *Calais* § *Calocalais* DC.

* Pappi paleæ 5, oblongæ seu lanceolatæ, apice mox lacerato-bifidæ et ex sinu aristam tenuem proferentes. Annuæ, radice exili.

14. M. Lindleyi. Acheniis præsertim extimis vix minusve rostratim attenuatis; pappi rufescenti-sordidi paleis achenio subæquilongis scaberulis oblongo-lanceolatis, costa valida ex emarginatura in aristam scabram ipsa parum breviorem

beak of the achenium is funnel-like or tubular! Also, that Dr. Palmer's plant from southern Utah appears to be of a second nearly related species. The diagnoses of the two may be expressed as follows: —

G. MARGINATA Eaton. Foliis insigniter scarioso-limbatis, summis bracteisque (involucrum circiter 12-phyllum 15–18-florum æquantibus) lacinulis fere filiformibus pectinato-marginatis; ligulis (an semper?) parvis; acheniis cinerascentibus, rostro infundibulari. — Nevada Desert, on the borders of California.

G. SETULOSA. Foliis margine parum callosis, dentibus superiorum calloso-setiferis; bracteis calyculatis involucro angusto 8–12-floro 7–8-phyllo dimidio brevioribus; acheniis glabris, rostro usque ad basim

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producta. — *Calais Lindleyi* DC. l. c. *Uropappus heterocarpus* Nutt. l. c. ex char. This occurs, mixed with the succeeding, in various collections, with which it has naturally been confounded, and it has sometimes been named *Calais Douglasii*.

15. M. LINEARIFOLIA. Foliis junioribus nunc pubescentibus seu villosulo-ciliatis; acheniis plerisque rostrato-attenuatis; pappi albi paleis achenio sæpius brevioribus lineari-lanceolatis apice mox acute bifidis, costa tenui ex sinu in aristam capillarem ipsa plus dimidio breviorem producta. — *Calais linearifolia* DC. l. c. excl. syn. *Uropappus linearifolius* & *grandiflorus* Nutt. l. c.

16. M. MACROCHÆTA. Pappi paleis oblongis arista sua tenuissima ex sinu exserente achenioque rostrato-attenuato 2–3-plo brevioribus. — *Calais macrochæta* Gray Pl. Fendl. & in Bot. Whipp. l. c.

* * Pappi paleæ 20–24, angustissimæ, in aristam scabridam sensim attenuatæ!

17. M. TROXIMOIDES. *Troximo cuspidato* similis, fere acaulis; radice perenni crasso nigricante; foliis crassiusculis linearibus sursum attenuatis integerrimis vel margine undulato; scapo spithamæo ad pedalem foliis 1–2 parvulis nunc instructo; involucro cylindraceo vel subturbinato 20–30-floro e squamis lanceolatis sensim acuminatis subæqualibus; pappo albido achenio lineari sursum parum angustato longiore. — Two forms are known: one from hills on the Clear Water River, Oregon (now Idaho Terr.), collected by Mr. Spalding, and mistaken for *Troximon cuspidatum*, also Montana Territory, from an unknown collector. This has a little pubescence about the head, unripe akenes rather strongly 10-striate-ribbed, and hardly tapering upwards. The other is no. 600 in the collection distributed by Kellogg and Harford, probably from the northern part of the coast of California. The single specimen I have seen of this has a wholly naked scape, a narrower and glabrous involucre, a whiter pappus, the achenia more lightly costate, and apparently more tapering upwards. This and *Troximon cuspidatum* indicate a clear transition between the two rather widely separated genera. The akenes of the present anomalous plant are about four lines long, glabrous: the pappus half an inch long, of uniform awnlike paleæ, which are flat and about a quarter of a line long to near the middle, thence gradually tapering into the slightly rigid and scabrous awn. Calyculate scales of the involucre hardly any.

cavo. — Near St. George, on the southern border of Utah, Dr. Edward Palmer.

MALACOTHRIX DC. In the Flora of North America, thirty years ago, and with very incomplete materials, I ventured to reconstruct De Candolle's *Malacothrix*, founded on a single species in flower only, by adding to it three genera which were shortly before characterized by Nuttall; and later, in Plantæ Fendlerianæ, I added another species of anomalous aspect. The characters which confirm this view have one by one come to light, except as to Nuttall's *Malacomeris*, of which nothing more is even now known. The genus was said to be "most allied to *Andryala*." The affinity thus suggested is strengthened by the discovery I have just made that the receptacle of *M. commutata* is foveolate and fimbrillate-toothed, and also that in other species, with foveolæ not apparent, there are delicate setæ, usually one to each of the areolæ of the receptacle, or to some of them. These are most conspicuous and persistent in *M. Coulteri*, apparently the most anomalous of the species, on account of its scarious involucre. In *M. sonchoides*, *M. obtusa*, &c., and in the original *M. Californica*, they are sometimes manifest (either caducous or persistent), but usually of extreme tenuity, yet sometimes evanescent or wanting.

In Plantæ Fendlerianæ I first noticed the stronger and few or solitary outer bristles of the pappus which characterize certain species of the genus, among them the original *Malacothrix* DC. The mention of *M. sonchoides* was in consequence of my having confounded with Nuttall's species of the Upper Platte two other more western species, one of which (*M. Fendleri*) has this character, and the other (*M. obtusa*) seemed to have it. Later, Dr. Torrey, in Stansbury's Report, corrected what he naturally thought an inexact statement, by saying that "in *M. sonchoides* I believe the outer series always consists of *five* bristles." Next, in Plantæ Wrightianæ, part 2, when distinguishing *M. Fendleri*, I too hastily adopted Dr. Torrey's view, without comparing his supposed *M. sonchoides* of Salt Lake, which has five or more strong persistent bristles, with Nuttall's original specimen, which has none. If it had, they would hardly have escaped Nuttall's attention, who described the whole pappus as soft and "quickly deciduous in the mass." In natural consequence, Torrey's species came to be well described in the Botany of King's Exploration as *M. sonchoides*, while the real *M. sonchoides* of that work, as respects the Utah specimens, is described as *M. obtusa*. In rectifying the synonymy, it will be proper to name the species which brought in this confusion *M. Torreyi*, in memory of its first describer.

To this genus I propose to append an imperfectly known species, of the southern borders of California, which has no pappus at all. It may prove to be a state of a pappose species.

A conspectus of the species, as now understood, is added in a note.*

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* MALACOTHRIX DC., Torr. & Gray.

§ 1. MALACOLEPIS Gray, Pl. Fendl. Involucrum gradatim imbricatum pluriseriale, e squamis latissimis albo-scariosis, costa tantum viridi. Herba annua, capitulis majoribus.

1. M. COULTERI Gray, l. c. Receptaculum setis capillaribus persistentibus inter flores onustum: ligulæ forte flavidæ demum purpurascentes. Pappus exterior e setis 1–2 validioribus lævibus fere persistentibus.

§ 2. EUMALACOTHRIX. Involucrum pauciseriale, e squamis angustis parum scariosis.

* Annuæ, leptophyllæ, capitulis solitariis majoribus scapos simplices terminantibus, involucri squamis gradatim imbricatis, floribus luteis. — *Malacothrix* DC.

2. M. CALIFORNICA DC. Laxe lanosa, nunc glabrata. Pappus exterior e setis 2 persistentibus cum denticulis nonnullis.

* * Annuæ, paniculato-ramosæ, capitulis minoribus, involucro plerumque biseriali, squamis interioribus æqualibus, exterioribus paucis brevibus calyculum referentibus, floribus pallide flavis demum purpurascentibus, foliis prasertim radicalibus runcinato-pinnatifidis. — *Leptoseris* Nutt.

+ Pappus exterior e setis validioribus nudis sat persistentibus 1–8.

3. M. TORREYI. Spithamæa ad sesquipedalem, fere glabra; ramis pedunculisque setis glanduliferis interdum parce munitis; capitulis mediocribus vel majusculis multifloris; involucro campanulato; achenio costis 5 subalato-prominulis insigniter angulato, valleculis bicostatis; pappo exteriori persistente e setis validis 4–8 (sæpius 5) denticulisque pluribus interjectis. — *M. sonchoides* Torr. in Stansbury, Rep. p. 392; Gray, Pl. Wright, 2, p. 105, p. p.; Eaton in Bot. King, p. 201, non Torr. & Gray, Fl. — From Salt Lake, Utah (Stansbury, S. Watson), to the western borders of Nevada (Anderson, S. Watson); and a slender, narrow-leaved form in southern Utah, collected by Dr. E. Palmer and Mrs. Thompson.

4. M. FENDLERI Gray, Pl. Wright, 2, p. 104. Humilis, fere glabra; involucro campanulato; achenio nigricante cylindrico æqualiter 15-costato, apice manifeste cupulato margine integerrimo; pappo exteriori persistente unisetoso. — New Mexico and Texas, on the Rio del Norte from near Sante Fé (Fendler) to El Paso (Wright) and still lower (Bigelow); also Guadalupe Cañon, Capt. Smith.

5. M. XANTI. Sesquipedalis, glabra vel glabrata; foliis fere omnibus radicalibus runcinatis membranaceis; caule scapiformi gracillimo polycephalo; involucro cylindraceo; achenio castaneo costis 15 obtusis striato ob 5 paullo validiores angulato, apice cupulato obtuse 5-dentato; pappo exteriori e setis

Crepis Cooperi = *Malacothrix crepoides* Gray, in Pacif. R. R. Expl. 12, p. 49, which is also no. 327 of Hall's Oregon collection. It

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3–5 gracillimis subperaistentibus. — *M. parviflora*? Gray, in Proc. Am. Acad. 5, p. 168, non Benth. — Cape San Lucas, Lower California, no. 67, coll. L. J. Xantus.

+ + Pappus exterior præter denticulos minimos plane nullus. Capitula parva.

6. M. sonchoides Torr. & Gray, Fl. Spithamæa, fere glabra; dentibus lobisve foliorum radicalium subspinuloso-apiculatis; acheniis fere linearibus 15-costatis ob costas 5 paullo majores sub-angulatis, apice haud contracto denticulis minimis albidis circa 15 coronulato. — *Leptoseris sonchoides* Nutt. in Trans. Amer. Phil. Soc. l. c. p. 488. *Malacothrix obtusa* Eaton, in Bot. King, l. c. quoad pl. Utah. — Upper Platte, Nuttall, Geyer (no. 40); Utah, S. Watson, Lieut. Wheeler.

7. M. obtusa Benth. Pl. Hartw. Spithamæa ad sesquipedalem; caulibus sæpius gracillimis amplius paniculatis subaphyllis; foliis radicalibus primum pl. m. albo-lanuginosis lobis dentibusque obtusis; acheniis obovato-oblongis pl. m. 15-costatis (costis secundariis aut prominulis aut fere evanidis), apice sub-contracto annulo integerrimo. — *M. parviflora* Benth. l. c. est forma scaposa microcephala. — California, common. In this species the capillary bristles of the receptacle are often very evident, about twice the length of the akenes, and deciduous with them, very fragile, resembling bristles of the pappus.

* * * Annuæ, scaposæ, platyphyllæ, involucro præcedentis, floribus purpureis albisve. Pappus nullus. — *Anathrix.*

8. M. platyphylla. Glaucescens; foliis dilatato-cuneatis venosis margine inæqualiter subspinuloso-denticulatis; scapo nudo ultrapedali superne laxe corymboso-ramoso polycephalo; involucri squamis propriis ovato-oblongis, accessoriis calyculi paucis brevibus. — S. E. California, in gravelly soil near Fort Mohave, Dr. J. G. Cooper.

* * * * Perennes vel biennes? basi nunc suffrutescentes. Receptaculum sub-alveolatum, alveolis dentatis.

+ Albifloræ (nunc purpurascentes), glabratæ, caulibus foliatis, capitulis sæpius paniculatis majusculis. — *Leucoseris* Nutt.

9. M. saxatalis. Tenuiter tomentulosa et glabrata, nunc fere glabra; foliis lanceolatis imisve oblongo-spathulatis nunc laciniato-pinnatifidis; acheniis lineari-oblongis 10-costatis, coronula prominulo 10-denticulato. — *M. saxatilis* & *M. commutata* Torr. & Gray, l. c. *Hieracium? Californicum* DC. *Sonchus? Californicus* Hook. & Arn. *Leucoseris saxatilis* & *Californica* Nutt. l. c. — Santa Barbara and southward.

10. M. tenuifolia Torr. & Gray, l. c. & Bot. Mex. Bound. p. 106. Glaberrima vel mox glabrata; foliis angustissime linearibus vel filiformibus sæpe 3–5-partitis; capitulis paucis in pedunculis filiformibus; acheniis obovatis, coronula obscura. — *Leucoseris tenuifolia* Nutt. l. c.? — In the Botany of the Mexican Boundary, I stated that "from three to five of the bristles of the pappus are

is evidently a *Crepis*, of the *Youngia* section, although the scales of the involucre become somewhat carinate, with a thickened midrib at maturity.

CREPIS OCCIDENTALIS Nutt. Nuttall could not have seen any well-formed fruit of this when he characterized on it his genus *Psilochænia*, as having achenia "without any visible striæ," and one of his own specimens given to me by himself, and one of Wyeth's original collection given to Durand, are in flower only. At maturity they are in fact strongly 10-striate-ribbed, fully as much so as in his own *Crepis* (*Leptotheca*) *acuminata*, with which the species is connected by such gradations that it is very difficult to distinguish the two. The most robust form of this variable *C. occidentalis*, which may be designated as var. *costata*, has the thicker and almost columnar achenia costate by 10 very strong and salient ribs. Var. *crinita* is a remarkable form from Oregon, with the involucre densely and the peduncles sparsely beset with long and tortuous whitish bristles.

TROXIMON Nutt. The union of *Macrorhynchus* Less. with Nuttall's *Troximon*, now made by Bentham, appears to have been unavoidable. *Troximon* might, perhaps, have been restricted to one of the two original species, *T. cuspidatum*, which has truly beakless columnar achenia, with only a slight narrowing or indistinct neck under the summit. The broad basilar areola is just that of *Scorzonera*, and the copious persistent pappus is remarkably rigid, some of the longer bristles being flattened and somewhat broadened downwards. This and the whole aspect of the plant suggests a real transition in earlier times between *T. cuspidatum* and the anomalous *Microseris troximoides*, described in a preceding note. But *T. glaucum*, with an evident although short beak to the mature achenium, and *T. aurantiacum*, with a more slender beak, and both with persistent pappus of intermediate character, show such a real gradation to *Macrorhynchus* as to render the reduction of Lessing's genus inevitable. These species, with *T. parviflorum* (*Macro-*

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more persistent and naked." I cannot now verify this statement, which was probably a mistaken one.

++ Flavifloræ, albo-lanatæ, foliis ad basin caulis confertissimis, pedunculo scapiformi 1–2-cephalo. Achenia ex Nutt. tenuiter 15-striata, coronula obsoleta. — *Malacomeris* Nutt.

11. M. INCANA Torr. & Gray, l. c. *Malacomeris incana* Nutt. — San Diego, on an island in the bay, Nuttall; known only from his imperfect specimens.

M. crepoides Gray, in Stevens, Exped. Pacif. R. R. Expl. is a *Crepis:* vide supra.

rhynchus cynthioides Hook.) and *T. roseum* Nutt. (which seem to be included among the many forms of the polymorphous *T. glaucum*), may constitute a section, *Nothotroximon*, characterized by the comparatively thick and nerved beak. *Macrorhynchus purpureus* Gray, Pl. Fendl., is still ambiguous.

In the section *Macrorhynchus*, characterized by the filiform or capillary and nerveless beak, the perennial N. American species are, —

T. APARGIOIDES Less. (*Macrorhynchus Lessingii* Hook & Arn., *M. humilis* Benth., and *M. Harfordii* Kellogg), of which it is well said that it resembles *Apargia autumnalis*. It has short achenia, with a scarcely longer beak.

T. NUTTALLII, which name is proposed for the *Stylopappus elatus* Nutt., this being by no means a tall species. It is known in fruit by its long achenia (about 4 lines) and comparatively short beak (3 or 4 lines in length).

T. GRANDIFLORUM, the *Stylopappus grandiflorus* Nutt. &c.; with capillary beak several times the length of the short-fusiform or oblong achenium. The typical form, with short and broad foliaceous outer scales to the large head, passes into var. *tenuifolium*, in Oregon (which is doubtless Nuttall's *Stylopappus laciniatus* var. *longifolius*), and apparently into smaller-headed forms, with narrower erect outer scales to the involucre, which, from Nuttall's description, should be his *Stylopappus laciniatus*, but his specimens seen are too young and of a doubtful look. Mature fruit of this form is needed.

T. RETRORSUM (*Macrorhynchus retrorsus* Benth. Pl. Hartw. and *M. angustifolius* Kellogg) is a related but well-marked species, both by the retrorse divisions of the leaves and the truncate apex of the achenium, from which the capillary beak abruptly springs.

Of annual species we have only one, polymorphous as to the achenia, viz.: —

T. CHILENSE, as it must be called; for I think Hooker and (later) Bentham correctly identify our northern species of the sort with *Macrorhynchus Chilensis* of Lessing; and I had long ago made out that Nuttall's *Kymapleura heterophylla* and his *Cryptopleura Californica* must be mere forms of one species. The latter was founded upon an abnormal and hypertrophied state of some of the outer achenia, which I have only once or twice detected; the former upon a more common condition, in which the ribs of many of the achenia develop into wings, which at maturity become either moderately undulated or much contorted, so as to imitate a loose corky coating.

LYGODESMIA Don. Probably Mr. Bentham has rightly referred to

this genus the ambiguous little plant named *Prenanthes ? exigua* in Pl. Wright, 2, p. 105. There is another and less incongruous annual or biennial species, with almost as white pappus, to be added. Well marked as the genus is in habit and flowers, it may be divided into nearly as many sections as there are species. The differences are exhibited below.* The genus differs from

STEPHANOMERIA essentially in the pappus only, and both genera have nearly the same geographical range, being characteristic Compositæ of our dry interior region. There are so few characters to hold to in the

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* LYGODESMIA Don, Torr. & Gray.

§ 1. Perennes, junciformes; involucro tantum calyculato; pappo molli sordescente. (*Lygodesmia* & *Erythremia* Nutt.)

1. L. JUNCEA Don. The original species. Heads about half the size of those of the next.

2. L. GRANDIFLORA Torr. & Gray. Foliosa; foliis graminoideis seu dianthoideis integerrimis. — To this belongs *L. juncea* of Durand's Utah Memoir, and the var. *dianthopsis* of Eaton in Bot. King, p. 200.

3. L. APHYLLA DC., cum var. TEXANA Torr & Gray. Caulibus totis vel superne aphyllis; foliis dum evolutis sæpe pinnatifido-laciniatis. — *L. juncea* Gray, Pl. Wright, 1, p. 129, no. 417, is an usually branching and more leafy form of this species.

§ 2. Perennes? divaricato-ramosissimæ; ramis spinescentibus; involucri squamis exterioribus gradatim brevioribus; pappo rigidulo sordido. (§ *Pleiacanthus* Nutt.)

4. L. SPINOSA Nutt. Perhaps only biennial; the crown producing a remarkable woolly tuft.

§ 3. Annuæ seu biennes; caulibus paniculatis; involucro tantum calyculato; pappo molli albo vel albido.

5. L. ROSTRATA. Bi–tripedalis, erecta, ramis adscendentibus laxe polycephalis; foliis angustissime linearibus elongatis, ramealibus in bracteas subulatas decrescentibus; pedicellis squamoso-bracteolatis; involucri 8–9-flori squamis propriis totidem angustissime linearibus elongatis; acheniis gracilibus apice subrostratim attenuatis. — *L. juncea* var. *rostrata* Gray, in Proc. Acad. Philad. 1863, p. 69. A good specimen of this, collected at Greeley, Colorado, in sandy soil, by E. L. Greene in 1872, shows the character of the root, akenes, and pappus, which mark it as wholly distinct from *L. juncea*.

6. L. EXIGUA. Spithamæa, a basi divaricato-ramosissima; foliis radicalibus spathulatis runcinato-subpinnatifidis, caulinis ramealibusque sensim in bracteas ovato-subulatas minimas decrescentibus; pedicellis subnudis; capitulis parvis; involucro 4–5-floro e squamis totidem lineari-oblongis cum bracteolis brevissimis 1–2; acheniis breviusculis columnaribus ab apice truncato deorsum parum angustatis inter costas 5 latas scabriusculas angustissime sulcatis. — *Prenanthes ? exigua* Gray, Pl. Wright, 2, p. 105. Collected only by C. Wright, in 1852.

Cichoriaceæ that we cannot let go those founded on the nature of the pappus. It seems necessary, however undesirable, to admit a third genus of the sort, founded on a single species, viz.:—

CHÆTADELPHA. — Capitulum 5-florum, liguliflorum. Involucrum cylindricum, e squamis 5 lanceolato-linearibus membranaceis dorso inferne carinatis achenia foventibus, cum exterioribus nonnullis calyculum referentibus. Receptaculum nudum. Ligulæ breves ut videtur roseæ. Achenia linearia, utrinque truncata, sub-5-angulata, leviter pauci-striata, apice lato subrepando. Pappus persistens, sordescens, pentadelphus, nempe e paleolis 5 aristiformibus rigidis nudis, cum setis rigidis utrinque 3–5 pl. m. brevioribus basi accretis. — Herba perennis, facie *Eulygodesmiæ*.

C. WHEELERI. Southern Nevada, on the borders of Arizona, Lieut. G. M. Wheeler, U.S.A. — An incomplete character of this was published by S. Watson in the American Naturalist, May, 1873, among other novelties of the region.

X.

A SINGULAR CASE OF CORROSION OF A TIN TANK.

By S. P. Sharples.

Read, May 12, 1874.

In June, 1872, I received a letter from the Collins Company, of Collinsville, Conn., of which the following is an abstract: —

This company has a hotel building in this place, supplied with very good spring water, which is conducted through, say 100 feet of lead pipe, from the cement pipe main in the street, to a very large tank or reservoir on an upper floor in the hotel. From this tank water is distributed all over the house, through lead pipes. Water is continually running into the tank, and of course is freely drawn off to the various points. The tank is lined with what the plumber calls pure block-tin. We observe that the water deposits white streaks, at various levels, around on the lining. Enclosed we send you a specimen of the tin lining and the white deposits or powder.

A waste pipe, 9 feet long by 2 inches in diameter, is within the tank, and subject to the action of the water.

Is the white powder from lead or any corrosive metal?

Subsequently they forwarded me specimens of the water taken from the spring, from the place where the lead pipe discharged into the tank, and from the place where it was drawn for use in the house.

The water taken directly from the spring was examined, and gave 5.3 parts inorganic matter, and 2.5 parts organic matter, to the 100,000 parts of water.

The inorganic portion was mainly carbonate of lime, with a little sulphate of lime and chloride of sodium. The specimens of water drawn from the lead pipes were entirely free from even traces of that metal. The white powder referred to was found to be oxide of tin, with a mere trace of iron. I accordingly reported that I did not think any harm would arise from the use of the water, — as the water was a pure one, and free from lead, — and that oxide of tin was not regarded as injurious.

On the 27th of March, 1874, the superintendent of the works again wrote as follows:—

"We enclose specimens of the lining of the tank which contained the water, the purity of which we were suspicious. We may be mistaken, but it does seem to us that the lining has been destroyed by the action of the water, in a most unusual manner. The tank lining has lasted only five years. There has been a free and ample circulation of fresh water constantly in use in the daytime, at the hotel, where our tank is located; and yet, for some cause unaccountable to us, the lining (which is block-tin) is perfectly riddled by corrosion, and must be replaced by a new one of some kind."

In answer to further inquiries on my part, he forwarded another specimen of the water, and a large piece of the lining of the tank, and further wrote:—

"The water is collected at the spring, in a sheltered and ventilated reservoir, with cement lining, and is conducted therefrom in a large cement pipe through our main streets. House pipes of lead are attached all along."

The water from the end of the pipe, where it discharged into the tank, was again analyzed, with the following results:—

Inorganic matter, 4.20; organic matter, 0.80 parts, in 100,000. Was perfectly free from nitrates; and, as the analysis shows, was rather better than when first examined. The lining is commercial block-tin, containing less than 2 per cent of impurities.

Instances of corrosion of lead are not uncommon; but I have failed, so far as I have investigated, to find a case parallel to this. Professor Chandler,* in an article on the use of tin-lined lead pipe, says, in speaking of tin-lined lead pipe: "Waters which take up one to two tenths a grain per gallon from lead pipe are not perceptibly affected by remaining for considerable lengths of time in the tin-lined pipes." And in another place, Mr. Cassamajor † states that tin is slightly more electro-negative than lead; and that it at first starts a feeble galvanic current, which serves to cover the lead with a coating of oxide, and then all action ceases.

Dr. Lankester ‡ states, in regard to the tin-lined lead pipes: "I have tested these pipes with great care, and have exposed them to the action of water of various kinds. In no case have I discovered in the water the slightest trace of lead or tin. I have submitted the pipes to the

* Am. Chem., Vol. II. p. 282. † Am. Chem., Vol. I. p. 3.
‡ Am. Chem., Vol. II. p. 27.

action of distilled water, Thames water, water from artesian wells in London, and to water highly charged with organic matter; and in no case, where these waters have been exposed to the usual reagents for detecting the presence of tin or lead, has the slightest quantity of these metals been detected."

Field* states that tin does not oxidize at ordinary temperatures in the air, and but very slightly in water, retaining its metallic lustre for a long time; and, again, it is not sensibly affected by the combined presence of air and moisture.

This extensive corrosion of the metal seems, therefore, to be a hitherto unrecorded circumstance, tin being generally regarded as the least liable to change of all our common metals. The metal, as will be seen, is entirely eaten through in some places.

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* Watts' Dict., Vol. V. pp. 808–4.

XI.

APPLICATIONS OF THE GRAPHICAL METHOD.

BY PROF. EDWARD C. PICKERING.

Read, May 12, 1874.

To establish any physical law, or the relation between two quantities so connected that a change in one produced a corresponding variation in the other, the following method is commonly adopted. A great many corresponding values of the two variables are determined with the greatest possible care, and corrected for all the errors to which they are known to be subject. Other errors known as accidental errors, however, still remain, whose minuteness depends on the excellence of the method of measurement and the care exercised. If now an equation can be found to satisfy all these values, its expression in common language will be the required law. Two methods are in common use to determine this equation. First, analytically, the form of the equation is assumed, and the values of the constants in it are found, by assuming certain of the observations to be correct; or, better, by the theory of probabilities employing all the observations, and computing from them the most probable values of these constants. The principal objection to this method is that it furnishes no means of discriminating between the accidental errors and the real variations from the law. In the second or Graphical Method, the two variables are taken as co-ordinates, and points are constructed corresponding to each observation. A curve is then drawn, coinciding with them as nearly as possible, and its equation determined by trial. The form of the curve shows very clearly the accidental errors or other causes of deviation; and the want of accuracy of this method, when the accidental errors are only small, may be completely overcome by the method of residual curves (Journal Franklin Instit., April, 1871).

There still remains, though in a less degree than in the Analytical Method, the difficulty of deciding whether a variation is due to errors, or to incorrect value of some of the constants taken. And it is to meet this difficulty that the following method is proposed.

With the exception perhaps of the circle, the straight line is the only curve of whose correctness every one is a judge; if, then, by any device we can so transform a curve that it shall become a straight line, a moment's inspection will show whether the agreement with observation is real.

Let us first take a special case, and then proceed to the more general discussion. A great many physical laws may be expressed by the equation $y = m\,x^n$, or that one quantity, y, is always proportional to some power of the other, x. For example, the variation of gravity, of the intensity of light, heat, and electric attraction, with the distance, may be stated $y = m\,x^{-2}$, or $n = -2$. For elastic forces, $n = 1$, or is proportional to the distance; for Mariotte's law, $n = -1$; for the deflection of a beam in terms of its length, $n = 3$, and so on. Sometimes n is a fractional number, or has a much larger value; thus Wertheim suggests that the laws of elasticity may be explained by assuming that the force of attraction of the particles varies at the 14th power of their distance apart. In the same way, Rankine adopts the exponents $n = -\frac{17}{16}$ and $n = -\frac{10}{9}$ for the variations of the pressure and volume of steam in the cylinder of an engine. Suppose now that we have a number of points constructed, and wish to see if they can be represented by any curve of the form $y = m\,x^n$. By drawing curves taking various values of n, as 1, 2, 3, $\frac{1}{2}$, &c., we may find one which will agree, but it will be difficult to be sure whether some other value will not give a more exact concordance. If, however, we take logarithms of both sides, and write log y = log m + n log n, and calling log $y = Y$, log $n = X$, and log $m = M$, construct a curve with Y and X as coordinates, we obtain $Y = M + n\,X$. If now the result is a straight line, or differs from a straight line only by the accidental errors, — that is, if there is no curvature to one side more than on the other, — we know that y varies as some power of x, and the value of n is readily determined from the tangent of the angle the line makes with the axis of X. In the same way m is obtained by finding the number whose logarithm is M, the ordinate of the point where the line meets the axis of Y. On the other hand, if the line is not straight, but curved, we may be sure that there is no value of n which will satisfy the observations, or that y is not proportional to *any* power of x. Let us next see how far this method may be generalized. In the first place, instead of x and y we may use any functions f and f' which include only x, y, and *known* constants; that is, which do not include m or n. For example, the equation $y^3 = m\,x^4 + n\,x^2$ may be written $\frac{y^3}{x^2} = m\,x^2 + n$,

or calling $Y = \frac{y^2}{x^2}$ and $X = x^2$, we have an equation of a linear form, $Y = mX + n$. We may then in general write:—

$$f = mf' + n \quad . \quad . \quad . \quad . \quad . \quad . \quad (1).$$

And, if one equation can be reduced to this form, we can readily determine whether there are any values of m and n which will satisfy it. Again, if we have:—

$$f = mf'^n \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (2),$$

we can reduce to a linear form by using $Y = \log f$ and $X = \log f'$. Another common case is:—

$$f = mn^{f'} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (3).$$

Taking logarithms $\log f = \log m + f' \log n$, from which $\log m$ and $\log n$, and hence m and n, are readily found. The most important application of this formula is when two quantities are so connected that if one varies in arithmetical progression, the other will vary geometrically. This is the case for the variations of the barometer for various heights, for the conduction of heat, and the loss of potential of an insulated cable by leakage. In all these cases we have $y = mn^x$, where x varies arithmetically and y geometrically, and from which m and n may be determined as above.

Probably the best way of illustrating these principles is by a few examples, in which, however, figures would be required to show the results most clearly.

1. *Torsion Pendulum.* Four observations were made on the time of vibration of a torsion pendulum when its length was varied. The results are given in columns 1 and 2 of the adjoining table. The 3d

TABLE I.

Length.	Time.	Log l.	Log t.	T.
1201.	6.3	3.08	.80	.80
949.	5.7	2.98	.76	.75
706.	4.8	2.85	.68	.68
445.	3.8	2.68	.58	.60

and 4th columns give their logarithms. On constructing the points with these co-ordinates, they fall very nearly on a straight line, as is shown by column 5, which gives values of $\log t$, computed by the for-

mula $C = \frac{1}{2} \log l + .75$. The close agreement shows that $t = m\sqrt{l}$, or that the time is proportional to the square root of the length.

2. *Force of Magnetism.* The observations given in Table II. were made by Professor Mayer (Amer. Jour. Sci., Sept. 1870), to determine the effect of a coil on a galvanometer needle placed at different distances.

TABLE II.

D.	Log *D.*	Log *f.*	*C.*
4	.602	.897	.900
5	.699	.627	.630
6	.778	.418	.418
7	.845	.234	.230
8	.903	.072	.071

The first column gives the distance, the second its logarithm, and the third the logarithm of the force produced, or the tangent of the angle of deflection. To see if $f = m\, d^n$, a curve was constructed, with columns 2 and 3 as co-ordinates, and appeared to coincide very closely with the line $y = -2.76\, x + 2.545$. Column 4 gives the values of $\log f$ thus computed, which shows a close agreement with observation. The result found by Professor Mayer was $n = 2.7404$; but the last two figures should be omitted, as they alter the result by only about one or two hundredths as much as the accidental errors.

3. *Resistance of Air.* Another excellent example is found in the resistance of air to projectiles. Newton assumed that the resistance was proportional to the square of the velocity, or $R = m\, v^2$; but this result is not sustained experimentally. The agreement with the cube of the velocity is, in fact, more exact; but neither is the true law. A more careful examination shows that the law alters for velocities above and below that of sound, or about 1,100 feet per second; since above that velocity the air cannot flow in rapidly enough to fill the space behind the shot, but leaves a vacuum. To show this, a series of observations with the Bashforth chronograph were examined, and showed in a marked manner the change when $i = 1{,}100$. No part of the curve, however, for either spherical or elongated shot becomes a straight line; and therefore no power of the velocity will give the correct value of the resistance.

4. *Conic Sections.* It often happens, especially in astronomy, that

having a number of points we wish to see if they lie on any curve of the second degree. For instance, suppose the polar co-ordinates of the various points given, with the pole at the focus: then $r = \frac{m}{1 + n \cos v}$, in which we wish to see if any values of m and n satisfy all the conditions. The equation may be written $\frac{1}{r} = \frac{1}{m} + \frac{n}{m} \cos v$, which becomes linear if $\frac{1}{r} = Y$, and $\cos v = X$. In the same way, if referred to its centre, $\frac{x^2}{m^2} + \frac{y^2}{n^2} = 1$, make $X = x^2$ and $Y = y^2$, when $\frac{1}{m^2}$ and $\frac{1}{n^2}$ are obtained.

5. *Periodic Functions.* In the study of periodic functions the equation $y = m \sin (n x + p)$ is assumed, in which m determines the maximum amplitude, n the period, and p the phase. If m is given $= a$, n and p may be found by writing $n x + p = \sin^{-1}\left(\frac{y}{a}\right)$, and using as co-ordinates x and $\sin^{-1}\left(\frac{y}{a}\right)$. If the period is given, or $n = b$, we have $y = m \sin b x \cos p + m \cos b x \sin p$, or, dividing by $\cos p$, $\frac{y}{\cos b x} = m \cos p \operatorname{tang} b x + m \sin p$, in which we may make $\frac{y}{\cos b x} = Y$, $\operatorname{tang} b x = X$, and thus determine $m' = m \cos p$ and $n' = m \sin p$. From these two equations we finally obtain $\operatorname{tang} p = \frac{n'}{m'}$ and $m = \sqrt{n'^2 + m'^2}$.

6. *Lissajous' Curves.* The wonderful variety of curves obtained by Lissajous, by mirrors attached to tuning-forks, may all be reduced to straight lines by this method. They may all be represented by the equations $x = \sin v$ and $y = \sin (m v + n)$, in which m represents the interval of the forks, and n the difference of phase. Eliminating v, we have $m \sin^{-1} x + n = \sin^{-1} y$, which at once takes the linear form when the co-ordinates $X = \sin^{-1} x$ and $Y = \sin^{-1} y$ are employed. To test this, a curve was drawn with an instrument devised by the writer (Journ. Frank. Inst., Jan. 1869), and forty-eight points on it measured, corresponding to variations of v of 30°. In the following table a portion only of the results are given. The first column gives various values of v, the second the measured value of the arc whose sine is y, or of $m v + n$. Constructing a curve with these co-ordinates, we obtain very nearly a straight line, with equation $y = \frac{34}{45} v + 4°$, from which we infer that the difference in phase of the two forks at 0° was 4°, and their interval a little more than a fourth (3 : 4), $\frac{34}{45} = .755$. The differences, as given in the fourth column, are very small, considering the roughness of the measurements.

TABLE III.

v.	$m\,v + n$.	$\frac{34}{45}\,v + 4^\circ$.	D.
0	0.	4.	—4.
180	139.	140.	—1.
360	276.	276.	0.
540	412.	412.	0.
720	544.	548.	—4.
900	685.	684.	+1.
1080	817.	820.	—3.

But it is needless to multiply these examples further. The method, in combination with that of residual curves, may be applied to almost any case where an empirical formula is to be deduced, and enables us to find the best values of two of the constants. A wide field seems to be open for it in astronomy; and it is to be regretted that heretofore astronomers should have neglected the graphical methods of discussing errors, as much as physicists have overlooked the more rigid analytical methods.

XII.

OCEAN LANES FOR STEAMSHIPS.

By Benjamin Peirce.

Read, May 12, 1874.

The present paper lays no claim to originality, or even to novelty. It will perform its desired function, if it should have any influence to effect a systematic organization of the paths of the Atlantic steamers, so as to remove the principal source of the dangers of collision. It aims to arouse public attention to the rapidly increasing magnitude of the peril, and induce action before there shall come the irresistible logic of terrible disasters following close upon each other. Such disasters have already occurred, and even at an early period, when the danger was not one-twentieth part of what it is now. When the number of steamers shall be tenfold what it is to-day, — which will occur in the next generation, — each steamer will be exposed to ten times the peril; and, as their number is tenfold, the whole number of collisions will be one hundred-fold its present number. There will be as many in a year as there are now in a century; and every year will have its cruel record of these fearful accidents.

The necessity of protecting the ocean from this danger, by assigning fixed limits to the routes of the steamships, was first considered as early as the year 1855, in a correspondence between the late M. F. Maury and numerous ship-owners and underwriters. This correspondence originated, I believe, with R. B. Forbes, Esq., of Boston; and I think it was then that the expressive designation of ocean lanes was introduced. The subsequent investigations of Mr. Maury referred especially to the ordinary sailing vessels and purely mercantile steamers, which should avoid the proposed lanes just in proportion as they are occupied by swift steamers, for whose use they are intended.

The subject has recently been taken in hand by Professor von Freden, of the North German Observatory, who has collated the routes of the various German steamers, and deduced from them what he regards as a proper route for each month in the year, and in each

direction. They are easily understood by a reference to the chart. It must be observed that the meridian of greatest danger is that of 50° west of Greenwich. This is the meridian of the Banks of Newfoundland, with its dense fogs, its squadrons of fishing-smacks, and its stranded icebergs. It is of the first importance to decide at what point this meridian shall be crossed; and, this point decided, it may not be necessary to impose any other restrictions as to the route to be pursued. All the western passages of the German routes cross the meridian of 50°, between the latitudes of 46° north and 43° 42′ north. The average length of these routes is only about six miles longer than the shortest route which could be pursued, but they cross the Great Banks near their widest and most dangerous part. The eastern German passages are of two classes for the three winter months of October, November, and December, which hardly differ from the shortest possible route, which is exactly the route for October. In the nine remaining months the passages are north of the western routes, crossing the meridian 50° between the latitudes of 44° 36′ north and 42° 30′ north. The two routes of May and June are included within the limits actually adopted for the western routes of the Cunard Line, and are thereby exposed to peculiar risk in the two months where there is the greatest danger from fog and ice. These lanes of the German astronomer are at present propositions, and have not been adopted by either of the lines. The objections to them are that they occupy too great a breadth of the ocean, and especially the whole extent of the Great Banks; that they are different in different months, thus losing the advantage of a single well-defined tract, and introducing perplexity and confusion as to which month each steamer properly belongs; that the opposing routes of different months overlap each other; and especially that the more southern of the eastern routes lie exactly in the track of the Cunard Line on their western passages.

The tracks which have actually been adopted by the Cunard Line are defined with extreme simplicity, and are in a very few words published in all the advertisements. "With the view of diminishing the chances of collision, the steamers of this line will henceforth take a specified course for all seasons of the year. On the outward passage, from Queenstown to New York or Boston, crossing the meridian of 53° at 43° latitude, or nothing to the north of 43°; on the homeward passage, crossing the meridian of 50° at 42° latitude, or nothing to the north of 42°." The singular brevity, conciseness, and completeness of these directions mark their author as a man of genius. They are dictated by a regard to that security of life which is the first duty of the

carrier of passengers. Uncompromising fidelity to this duty, and unfailing good judgment in its execution, seem to have secured to this line the unexampled favor of good fortune, or more justly have constituted their good fortune. The routes of the Cunard Line reduce the dangers to the least amount; and, being the same at all seasons, there can be no uncertainty regarding them. I venture, then, to press upon this Academy the expediency of using its influence to induce the other lines of Atlantic steamers to adopt the Cunard routes. It is essential to the success of the system that it should be universally adopted. I am sure you will regard the object as worthy of the earnest action of the Academy. It is important to consider the agencies through which the system must be introduced; whether there be any action of Grovenment which will be required, or whether the whole subject should be left to the ship-owners and underwriters. Some clause introduced into marine policies might be wise and effective, and it might be well to subject all the logs of the steamers to some officer of acknowledged judgment, from whom an unfavorable report would be received as a serious sentence, and one greatly to be dreaded. But, even when the lanes are established, there will still remain considerable danger, unless the steamers are required to assume a uniform speed — say of ten knots an hour — during the continuance of a fog. With these suggestions, I leave the subject in the hands of any committee which may be appointed.

PROCEEDINGS.

Six hundred and fifty-eighth Meeting.

May 27, 1873. — ANNUAL MEETING.

The PRESIDENT in the chair.

Mr. Denny presented the report of the Treasurer, which was recommitted to be acted upon at the next meeting.

The Chairman of the Rumford Committee presented his report, which was accepted.

In accordance with this report, it was voted unanimously to award the Rumford Medal to Mr. Lewis M. Rutherfurd, of New York, for his improvements in the processes and methods of astronomical photography.

It was voted to defer action on the appropriations until the adjourned meeting.

It was voted to adopt the change in Chapter IX., Section 2, of the Statutes of the Academy, as proposed at the meeting of March 11.

The verbal changes required by this vote in the latter part of the section were referred to a committee consisting of Messrs. Joseph Lovering, C. W. Eliot, and A. P. Peabody.

The following gentlemen were then elected members of the Academy: —

R. J. E. Clausius, of Zurich, to be a Foreign Honorary Member in Class I., Section 4.

J. J. Sylvester, of Woolwich, to be a Foreign Honorary Member in Class I., Section 1.

C. F. Naumann, of Leipzig, to be a Foreign Honorary Member in Class II., Section 1.

Also the following gentlemen, previously Resident Fellows, were elected Associate Fellows in their respective sections: —

Charles H. Davis, Class I., Section 2.
C. E. Brown-Séquard, Class II., Section 3.
W. W. Story, Class III., Section 4.
James E. Oliver, Class I., Section 1.
George W. Hill, Class I., Section 2.

The annual election resulted in the choice of the following officers: —

Charles Francis Adams, *President.*
Joseph Lovering, *Vice-President.*
Josiah P. Cooke, Jr., *Corresponding Secretary.*
Edward C. Pickering, *Recording Secretary.*
Edmund Quincy, *Treasurer and Librarian.*

Council.

John B. Henck, Benjamin Peirce, Wolcott Gibbs,	of Class I.
Charles Pickering, Alexander Agassiz, Asa Gray,	of Class II.
Robert C. Winthrop, George E. Ellis, Andrew P. Peabody,	of Class III.

Rumford Committee.

Morrill Wyman.	James B. Francis.
Wolcott Gibbs.	John M. Ordway.
Josiah P. Cooke, Jr.	Stephen P. Ruggles.

Edward C. Pickering.

Committee on Finance.

Charles Francis Adams, } *ex officio.*
Edmund Quincy, }
Thomas T. Bouve.

The other Committees were appointed, on the nomination of the President, as follows: —

Committee on Publication.

ALEXANDER AGASSIZ. W. W. GOODWIN.
JOHN TROWBRIDGE.

Committee on the Library.

CHARLES DEANE. WILLIAM WATSON.
HENRY P. BOWDITCH.

Auditing Committee.

HENRY G. DENNY. ROBERT W. HOOPER.

Professor Benjamin Peirce moved that the thanks of the Academy be presented to the retiring President for the very eminent manner in which he had fulfilled the duties of that important office.

The Annual Report of the Council, parts of which had been read at former meetings, was presented in full by Professor Joseph Lovering, the retiring Corresponding Secretary.

Since the last report of the Council the following additions, by election, have been made to the membership of the Academy: —

W. R. Nichols, of Boston, to be a Resident Fellow in Class I., Section 3.

C. L. Jackson, of Cambridge, to be a Resident Fellow in Class I., Section 3.

C. O. Boutelle, of United States Coast Survey, to be a Resident Fellow in Class I., Section 4.

J. M. Merrick, of Boston, to be a Resident Fellow in Class I., Section 3.

N. St. J. Green, of Cambridge, to be a Resident Fellow in Class III., Section 1.

H. H. Hunnewell, of Wellesley, to be a Resident Fellow in Class II., Section 2.

H. P. Bowditch, of Boston, to be a Resident Fellow in Class II., Section 4.

William T. Roepper, of Bethlehem, Pa., to be an Associate Fellow in Class II., Section 1.

J. H. W. Döllen, of Pulkowa, to be a Foreign Honorary Member in Class I., Section 2.

William Thomson, of Glasgow, to be a Foreign Honorary Member in Class I., Section 4.

Theodor Mommsen, of Berlin, to be a Foreign Honorary Member in Class III., Section 3.

James Martineau, of London, to be a Foreign Honorary Member in Class III., Section 1.

Benjamin Jowett, of Oxford, to be a Foreign Honorary Member in Class III., Section 2.

Karl F. Rammelsburg, of Berlin, to be a Foreign Honorary Member in Class II., Section 1.

Since the last annual meeting, the Academy has lost by death six Resident Fellows, five Associate Fellows, and six Foreign Honorary Members.*

Albert Hopkins was born in Stockbridge, Mass., July 14, 1807, and died in Williamstown, May 25, 1872. He graduated at Williams College in 1826. In 1827 he was elected Tutor in the College, and in 1829 was called to the Chair of Mathematics and Natural Philosophy. He then visited Europe, mainly at his own expense, and purchased apparatus for the College, — valuable and ample for those times. After his return, in 1835, he built the Astronomical Observatory for the College, mostly from his own means. In 1838 the title of his chair was changed to that of "Natural Philosophy and Astronomy," and in 1869 he was made "Memorial Professor of Astronomy," and relieved of all other duties.

Sickness in his family, for many years, interfered with original work, but for more than forty years he was a laborious and successful officer of College. He not only kept alive an interest in his own department by his faithful instruction, but in the early days of his Professorship, in connection with Eaton and Emmons, he did much to encourage study in the different departments of Natural History.

* The biographical notice of Daniel Treadwell, not having been prepared in season to take its place in the Council's Report of last year, was to have been appended to the present report. Meanwhile the Academy has invited Dr. Morrill Wyman to prepare a fuller memoir of Mr. Treadwell, which will take the place of the customary biographical sketch.

He published no works of importance, but left an Astronomy in manuscript.

1. As a professor, he did a great work for Williams College.
2. As a preacher, he has been rarely surpassed in power.
3. As a man, he commanded the esteem and admiration of this whole community, — from the lowest to the highest, — as no other man has, in the whole history of the town and College.

Brevet Brigadier-General Sylvanus Thayer, of the United States Engineer Corps, died at his residence in South Braintree, on Saturday, September 7, 1872, at the age of eighty-seven years. Born in Braintree, in humble circumstances, on the 19th of June, 1788, he entered Dartmouth College, and graduated in the class of 1807 with high honors. His tendencies being to a military life, he entered West Point, March 20, 1807; and on the 23d of February, 1808, he graduated, and was promoted in the army to a second lieutenancy in the corps of engineers. After leaving West Point, he reconnoitred the country lying about Lake Champlain and Lake George, during which time his means were reduced to so low a point that he sold from time to time his honorary medals to obtain food and lodging, redeeming them years afterwards. His second military employment was in surveying sites and projecting plans for batteries at New Haven and Stonington Harbors, and in inspecting Fort Trumbull, Connecticut. He subsequently served as assistant engineer in constructing the defences of the Massachusetts coast; in the same capacity at the Military Academy; and also at the fortifications in New York Harbor, where he afterwards served as assistant ordnance officer. He was promoted to a first lieutenancy in the corps, July 1, 1812; and during the war with Great Britain served as chief engineer of the northern army, under command of Major-General Dearborn; of the right division of the same army, under command of Major-General Hampton, to whom he was also aide-de-camp, engaging in the combat of Chateaugay River, October 26, 1813, just previous to which he had been promoted to a captaincy. Captain Thayer was chief engineer of the defences of Norfolk, Va., in 1814, under the command of General Porter, and received the brevet of major in February, 1815, for distinguished and meritorious services. In company with Colonel McRae, he in the same year visited Europe on professional duty, examining fortifications, military schools, and the operations of the allied armies occupying France on the fall of Napoleon I. Returning to the United States in 1817, his extraordinary acquirements secured for him the superintendency of the

Military Academy at West Point, on July 28, a position which he held until July 1, 1833; during which time he was thrice promoted, and retired with the respect of those with whom he was immediately connected in the departments of instruction, and with a reputation as a disciplinarian unequalled by any of his predecessors. After leaving West Point, he was engaged in superintending the construction of Forts Warren and Independence, in Boston Harbor, — a work which he attended to in person for ten years, in connection with the other duties assigned him in that period; namely, the general supervision of harbor improvements and coast defences in Maine and Massachusetts. Fort Winthrop, now far advanced toward completion, was begun under his direction, as were also the harbor improvements, now in progress under the supervision of General Benham. The interval between 1858 and 1863 was passed on sick leave of absence. Upon his resumption of duty, he received the full rank of colonel of engineers, and a month later was brevetted brigadier-general for long and faithful service. General Thayer was twenty-five years of his active service a member of the board of engineers for coast defences, and nineteen years its president; in command of the corps of engineers in 1858; and a member of various special engineer, ordnance, and military boards from 1825 to 1858. He retired from active service June 1, 1863, having been borne on the army register more than forty-five years.

General Thayer received the degree of A.M. from Dartmouth College in 1810, and from Harvard University in 1825; LL.D. from St. John's College, Maryland, in 1830; from Kenyon College, Ohio, and Dartmouth College, in 1846; and from Harvard in 1857. He was elected a Fellow of this Academy in 1834. He was also a member of the American Philosophical Society of Philadelphia, and of various other scientific societies.

To General Thayer, as superintendent of the Military Academy, the country owes a debt of gratitude. During his administration the whole organization was remodelled; and the discipline and instruction placed upon that firm basis which has ever since withstood the assaults of its enemies, and earned for our national school its well-merited reputation.

In his later years, while engaged in constructing Fort Warren, he was the same rigid disciplinarian, imperious, despotic, brooking no interference where his will was law, and perhaps more feared than loved by those who served under him. He had that high administrative ability which exacts the utmost from all its agents: his eye was everywhere, even upon the hod-carrier who worked under him; and any delinquency or

error was sure of detection. The forts in Boston Harbor have been the training-school of many of the best master mechanics of the State; and no one of them will ever forget the stately majesty of his figure, as he appeared before them, day after day, with a large expanse of ruffled shirt-bosom, a black hat and cotton umbrella, and stood for hours, under a broiling July or August sun, superintending the dumping of an earth-cart in the precise spot pointed out by his umbrella, with as much apparent interest as if he were locating a siege-gun.

General Thayer was never married; and the considerable wealth which he accumulated during a long life of public service, distinguished by strict faithfulness and unswerving integrity, he devoted to public uses. His college and native town received the chief share of his benefactions; but our Academy was not forgotten, and enjoys a legacy of one thousand dollars from his estate.

Charles Folsom was born at Exeter, N.H., on the 24th of December, 1794, was elected a Fellow of the Academy in 1827, and died on the 8th of November, 1872. He was prepared for college at Phillips Academy in his native town, joined the Sophomore Class of Harvard University in 1810, and was graduated with high reputation as a scholar in 1813. During the year following he took charge of the Academy at Hallowell, Maine, then returned to Cambridge to study divinity as a resident graduate. In the spring of 1816, upon President Kirkland's recommendation, he accepted the appointment of chaplain and schoolmaster to the midshipmen of the flag-ship of Commodore Chauncey, and his successor Commodore Bainbridge, destined for the Mediterranean squadron. Here Admiral Farragut was one of his pupils; and when, in the autumn of 1817, Mr. Folsom was appointed consul *ad interim* at Tunis and left the ship, the young midshipman Farragut obtained leave to accompany him and to continue his studies under his direction. They remained at Tunis for more than two years, and until the arrival of a successor in the consulate, and then rejoined the squadron. In after years the distinguished Admiral was never weary of acknowledging how much he owed to his early friend and tutor, for whom he always manifested the most affectionate and reverential regard. Returning to Boston in 1821, he was appointed Tutor in Latin in Harvard University, was two years afterward made Librarian, and officiated for a year or more as Instructor in Italian. He subsequently became a partner in the printing-house bearing the name of the University Press, and in this relation took charge of the proof-reading, in which delicate func-

tion he was unsurpassed, perhaps unequalled, for his critical accuracy and severe taste. He afterward kept for several years a school for young ladies in Boston, and was at a still later period Librarian of the Boston Athenæum. He was the author, so far as is known, of no original works; but edited a selection from Cicero's Orations, and a series of excerpts from Livy, with valuable annotations of his own, both which books had and deserved an unusually long currency in our classical schools. He was also associated with Mr. Bryant, in 1824, in editing the "United States Literary Gazette;" and in 1833 and 1834 he edited, in connection with Mr. Norton, the "Select Journal of Foreign Periodical Literature." His later years were devoted to congenial literary pursuits, until he was disabled from all mental exercise by repeated attacks of paralysis, under which his powers gradually yielded.

He married, in the autumn of 1824, Susanna Sarah, daughter of the Rev. Professor McKean, who survives him. He was for almost half a century an interested and influential member of this Academy, and for several years its Corresponding Secretary.

He was particularly distinguished as a Latin scholar; and, though he must have been but imperfectly acquainted with the light recently thrown from the East on the classic tongues, it is believed that in this one department he was second to no American of his own generation. He was also familiar with the best English literature, and in bibliography he especially manifested both extensive knowledge and keen discernment. He was an accomplished, indeed fastidious, literary critic, endowed with what has been well characterized as "a passion for exact and minute accuracy." In domestic and social and in all the relations of life, Mr. Folsom was a man of kindly and most unselfish spirit, and of the sweetest temper. Few men have had firmer, more persistent, or more worthy friends than he had among the best and most distinguished of his coevals.

JOSEPH HALE ABBOT was born at Wilton, N.H., September 25, 1802, and was seventy years, six months, and thirteen days old at the time of his death, April 7, 1873. His father was Ezra Abbot of Wilton, who was fifth in descent from George Abbot, who emigrated from England in 1640, and with other individuals of the name of Abbot settled in Andover, Mass., in 1643.

His mother was Rebekah Hale, of Coventry, Conn., a niece of Captain Nathan Hale of Revolutionary memory, and a descendant in fourth degree from the Rev. John Hale, first minister of Beverly, Mass.

Mr. Abbot was named for his maternal grandfather, Joseph Hale, brother of Nathan, himself also a soldier in the Revolution.

Mr. Abbot began his preparation for college as a private pupil under the instruction of the Rev. Thomas Beade of Wilton, at the age of twelve, and finished it under the charge of his uncle, the Rev. Dr. Abiel Abbot, principal for some years of Dummer Academy at Byfield, in 1818. He always attributed whatever he had of thoroughness in his classical studies to the excellent drilling he received from this venerated relative.

He entered Bowdoin College at Brunswick, graduating in 1822.

For the next three years he spent his time partly at Cambridge, as a resident graduate, attending lectures and pursuing various studies; and partly in teaching, at Watertown and Beverly. Late in the autumn of 1823, he began at Beverly a select school of twenty-five pupils of both sexes, conducted entirely according to his own ideas of teaching. This he always considered his first school, and it is now remembered as having given great satisfaction to its six proprietors.

He left Beverly in the autumn of 1825 to become Tutor of Modern Languages and Librarian at Bowdoin College.

From 1827 to 1833 he was Professor of Mathematics and Natural Philosophy and teacher of modern languages at Phillips Academy, Exeter.

At the close of this term of service, his health requiring a change in his mode of labor, he removed to Boston, and in September, 1833, opened a school for young ladies, which, with some intermissions, he sustained with ability for more than twenty-five years.

In the spring of 1861 Mr. Abbot returned to Beverly, and by invitation of the citizens took charge of the High School required by State law in that town. In this school he taught with great success, his labors having been much commended.

When his youngest son was prepared to enter Harvard College, Mr. Abbot disposed of the old family mansion at Beverly, and came to Boston and took rooms in Pemberton Square, where he received a few private pupils and where he continued his own studies.

In the spring of 1872 Mr. Abbot's health suffered a severe shock, and his debility continued to increase during the summer, so that he was unable to continue his scientific and literary labors. He removed to Cambridge, residing in the family of his daughter, and still hoping to be able to complete his new English Grammar, a work he had in preparation for some fifteen years past, and which would have proved of great value to the public, had it been completed and published. Of

Mr. Abbot's scientific works but few have been published, and he was so scrupulous and carefully conscientious that he was unwilling to give to the public any thing which he was not quite sure was perfect.

He gave lectures occasionally on scientific subjects. One on Heat he delivered before the Lyceum of Exeter in 1831; and he also delivered a course of lectures to ladies in Boston, in 1833–34, on Natural Philosophy, which proved very acceptable to persons fully qualified to judge. In 1839–40 he gave lectures on Electro-magnetism at Lyceums in Boston, Salem, and Beverly; and in 1857 he gave, by special request, two courses of lectures to ladies in Pemberton Square, his subject being Natural Philosophy. In 1855 he was engaged as a lecturer at the Lowell Institute, his subject being Meteorology; but illness prevented his delivering the course.

In 1840 he published in the "American Journal of Science" an article entitled "An Attempt to determine by Experimental Research the Theory of the Pneumatic Paradox." About the same time he read to the Academy a communication explaining a curious phenomenon in hydraulics, which he illustrated by experiments with ingenious apparatus of his own invention.

In 1848 Mr. Abbot published in "Littell's Living Age" a paper entitled "Principles recognized by Scientific Men applied to the Ether Controversy." In June, 1868, he published in the "Atlantic Monthly" a second paper on the same subject, entitled "The Discovery of Etherization." In 1857 he undertook the revision of the definitions of the scientific terms of Worcester's Dictionary.

Mr. Abbot was a ripé scholar, thoroughly versed in the classical and several of the modern languages, and a zealous student and experimenter in science. He was for a number of years the Recording Secretary of the Academy; and his records show his remarkable powers of condensation without loss of any material fact or principle, and may be regarded as models of their kind.

Mr. Abbot married Fanny, daughter of Captain Henry Larcom, of Beverly; and, of his seven children, five are now living.

Henry C. Perkins, M.D., the son of Thomas and Elizabeth Perkins, was born in Newburyport, November 13, 1804. He commenced the study of Latin at eight years of age, under Michael Walsh, an eminent teacher, then residing in that city, and author of an Arithmetic of considerable reputation. He fitted for college at the Newburyport Academy, and graduated at Harvard in the class of 1824. He pursued his medical studies with Drs. Richard S. Spofford, of Newburyport, and

John C. Warren, of Boston. In August, 1827, he took his doctor's degree, and soon after commenced the practice of medicine in his native place, and had a professional life of a little more than forty-five years.

He was a hard student, and ever enthusiastic in the pursuit of knowledge. Not confining himself to medicine and the allied sciences alone, he extended his investigations in a great variety of directions. He undertook the grinding and polishing of the lenses for a telescope. He experimented in the qualities of chloroform and ether as anæsthetics. Some fossil bones, which came into his possession, led him to the study of comparative anatomy. He calculated the orbits of comets; he engraved; he made for himself a microscope; was the first in this country to follow Daguerre in his remarkable discovery; was a student of Meteorology; and after he was sixty-five years of age learned the German language, that he might translate a work of Hallier on the germs of disease.

He was highly esteemed in the community as a citizen and a man. He was two years a member of the Common Council, and its President; a member of the Legislature. He was a trustee of the Putnam free school, a director in the Public Library, a Fellow of the American Academy of Science, a trustee of the Peabody Fund in Newburyport, for some years a member of the committee for examining the Cambridge Observatory, for two years President of the Massachusetts Medical Society, and also a member of several other scientific bodies. He was appointed by Mr. George Peabody one of the trustees of the fund appropriated for the promotion of science and useful knowledge in the county of Essex, and since its incorporation one of the "Trustees of the Peabody Academy of Science."

He was simple, earnest, intelligent, and a close student of nature. He led a pure life and one of untarnished integrity, and in all his transactions was truthful and honest.

The life of Dr. Perkins presents a beautiful example of a critical scholar, yet a devout Christian believer; a man of science, yet a man of God; a friend of progress, and yet holding fast to all that was good and true; a physician by profession, but a friend and helper by choice.

The Hon. James Savage was born in Boston on the 13th of July, 1784. His father was Habijah Savage, of Boston, and his mother Elizabeth Tudor, daughter of John Tudor, also of that city. Mr. Savage was descended from Major Thomas Savage, an early settler of Boston, and Faith Hutchinson, daughter of the famous Ann Hutchin-

son. At an early age he entered Derby Academy at Hingham, and subsequently Washington Academy at Machias, Maine. At the age of fifteen he entered Harvard College, and graduated in 1803. Three years later he took his master's degree. In 1805, owing to feeble health, he visited, in company with a relative, St. Domingo, Demerara, Jamaica, and other of the West India Islands. He studied law with Chief Justice Parker, Samuel Dexter, and William Sullivan, and was admitted to the Suffolk bar in 1807.

Mr. Savage's name will be found largely associated with the civil, literary, and benevolent institutions of the city of Boston. Early a member, he was for a time secretary, of the Anthology Society, of whose organ, the "Monthly Anthology," he was for five years editor. He was one of the founders of the Boston Athenæum. In 1811 he delivered the oration before the authorities of the city of Boston, and in the following year the oration before the Phi Beta Kappa Society at Cambridge. This year (1812), he was first elected a representative to the General Court. Subsequently he became a member of the State Senate and of the Executive Council. He was a member of the convention for the revisal of the State constitution in 1820, having the year before again visited Demerara. He was elected to the Common Council of the city of Boston, first in 1823, and was afterwards a member of the Board of Aldermen and of the School Committee.

Mr. Savage's literary labors have been extensive. His connection with the "Monthly Anthology" has already been referred to. On the establishment of its literary successor, the "North American Review," in 1815, he became a contributor to its columns. He revised for the press the volume of "Charters and General Laws of the Colony and Province of Massachusetts Bay," published under a commission of the State in 1814, and prepared an Index for the same. In 1825 and 1826 he published a new edition, in two volumes, of Governor Winthrop's History of New England. The occasion of the preparation of this edition was the discovery, or more properly the *recovery*, in 1816, in the tower of the Old South Church in Boston, of the third MS. volume of this History, in the autograph of the author. Here the Rev. Thomas Prince, the annalist, the pastor of that church, who died in 1758, had kept his library. Prince, in 1754, had announced that he had "lately received a most authentic and valuable *Journal* of Events relating to said [Massachusetts] Colony, . . . *viz.*, From *Monday*, *March* 29, 1630, to *Jan.* 11, 1648, 9, . . . all wrote with . . . GOV. WINTHROP'S own Hand, who deceas'd in the very House I dwell in on the 26th of

March after." This was the entire History in three MS. parts or volumes. He had undoubtedly borrowed them of the Winthrop family. The first and second volumes had been returned, and by consent of the proprietors were transcribed and published at Hartford in 1790, in one volume. The third volume had been overlooked, and was therefore not included in the Hartford publication, and had never been published. On its discovery in 1816, in Prince's library, which he had bequeathed to the Old South Society, it was presented to the Historical Society. By them it was committed to Mr. Savage. While engaged in copying and preparing this MS. for the press, Mr. Savage carefully collated the first and second volumes * with the corresponding printed volume of 1790; and he soon saw the importance of preparing a new edition of those two volumes, to be published in connection with the third, the newly discovered volume. Various circumstances, including two absences from the country, occasioned delay in the publication of the work. On its appearance, largely annotated by its editor, this work gained for Mr. Savage the highest reputation as a New England Antiquary.

In January, 1832, Mr. Savage delivered a lecture before the Massachusetts Lyceum on the "Constitution of Massachusetts," which was published in the March number of the "New England Magazine" in that year. In his connection with the Massachusetts Historical Society, to which he was elected a member in 1813, Mr. Savage found a field of labor eminently congenial to his tastes and to his talents. Of this institution he was Librarian four years; a member of the Publishing Committee of five volumes of its Collections; Treasurer nineteen years; a member of the Standing Committee nine years; and President from 1841 to 1855, — fourteen years. In 1842 he visited Europe, and made valuable collections of materials to illustrate our early history, part of which he published in the "Collections" of the Society, under the head of "Gleanings for New England History."

As chairman of a committee of the Pilgrim Society, appointed in 1849, Mr. Savage in the following year made a report on the subject of the calendar for old and new style, demonstrating that the Society had hitherto chosen the wrong day to celebrate the landing of the

* Volumes one and two of the original manuscript had already been transferred to the Society's library (see Proceedings Mass. Hist. Soc. for June, 1872, pp. 233–236). The second volume was unhappily destroyed by fire, with Mr. Savage's copy and notes, while the work was going through the press (see Savage's Winthrop, vol. ii. pp. 13, 200, 201, notes). Volumes one and three are still in the Historical Society's library.

Pilgrims, — that December 21st, new style (instead of the 22d), corresponded to December 11th, old style, the day of the landing. The error occurred in this way: In 1769, when the celebration of this event was first instituted at Plymouth, *eleven* days was the true difference between old and new style, and this difference was erroneously assumed to represent the true day of the landing in 1620; whereas but *ten* days were required. Mr. Savage also pointed out many other errors in chronology which occurred in the same way.

In 1853 Mr. Savage published a new edition of Winthrop's History of New England, "with additions and corrections." After the completion of this labor, he devoted himself unremittingly to the preparation of his last great work, "A Genealogical Dictionary of the First Settlers of New England, showing Three Generations of those who came before May, 1692, on the basis of Farmer's Register," in four large octavo volumes. The first and second volumes appeared in 1860, the third in 1861, and the last in 1862. This work must ever be regarded as a monument of persistent labor and industry, on a subject to most persons dry and uninviting. In the preface to the first volume he says, "In fulfilment of this great undertaking, more than fifteen years are already bestowed, and near two years longer may be necessary."

Mr. Savage was an Overseer of Harvard College from 1838 to 1853, and in 1841 that institution conferred upon him the degree of LL.D. He was the founder of the "Provident Institution for Savings" in the city of Boston. While on a visit to his friend the late Benjamin Vaughan, of Hallowell, in 1816, he met with one of the reports of the "London Provident Institution," an examination of which deeply impressed him with the importance of establishing a similar institution in the city of Boston. He laid the subject before a number of prominent citizens, some of whom approved of the scheme, while others gave no encouragement. Mr. Savage persevered, and the Provident Institution was established. From 1817 to 1862, a period of forty-five years, he was successively its secretary, treasurer, vice-president, and president; and for the greater part of this long service absolutely declining all compensation. During his absence in Europe in 1842, his associates procured a marble bust of him to be made, by a Boston artist, from a model previously prepared, and placed it in the vestibule of their hall, as an enduring memorial of their founder. For many years he was a member of the religious society of which the Rev. William E. Channing, D.D., and the Rev. Ezra S. Gannett, D.D., were the ministers, and in 1834 he was unanimously chosen deacon of the church; and his devotion to these eminent men ended only with their lives. Indeed, in

his last will he bequeathed a sum of money for the education of an infant grandson of Dr. Gannett.

This sketch must be regarded as a mere outline of an industrious life filled with good deeds, and with noble endeavors crowned with success. Mr. Savage had marked traits of character. He formed his opinions in the light of his own independent judgment, and was fearless in expressing them. Though sometimes a little impatient of contradiction, his thoroughly honest and unselfish motives gained for him the respect of all who were blessed with his acquaintance. During the last few years of his life his mind was seriously impaired, and he retired from public notice. He died in the city of his birth on the 8th of March, 1873; and the announcement of his death revived in the community the recollection of one of the most useful and valued of its citizens. By his last will, dated 25th January, 1867, he bequeathed forty thousand dollars to Harvard College, the income to be applied, first, to the support of one scholarship, not to exceed three hundred dollars, and the surplus income to be divided between the Library and the Astronomical Observatory. He also gave to the College the privilege of selecting one hundred volumes from his library. To the Historical Society he left five thousand dollars, the income of which was to be used for the increase of its library; also his cabinet of coins, and one hundred volumes of books, to include his private copy of Winthrop's History and that of his Genealogical Dictionary (six volumes), containing manuscript additions and corrections. Subsequently, additional volumes from his library, and his papers relating to historical and genealogical inquiries, were presented to the Society by his family.

In 1823 Mr. Savage married Elizabeth Otis, the widow of James Otis Lincoln, and daughter of George Stillman, of Machias, Maine. Their children were one son and three daughters. One of the daughters married Professor William B. Rogers, late President of the Technological School in Boston; another married the late Amos Binney, of the same city. James, the son, was an officer in the Second Massachusetts Volunteers (infantry), during the late civil war, and died at Charlottesville, Va., October 22, 1862, of wounds received at Cedar Mountain. Of his children, Mrs. Rogers only survives him.

FRANCIS LIEBER, at his death in October last, stood at the head of political writers in this his adopted country. He deserves a more extended tribute, on account of his services as a man and a publicist,

than we can pay to him within our limits. And his merits are so much the greater, in that, although born and trained under other forms of government, he thoroughly comprehended our political system, was loyal to it, was as true and as intelligent a friend of the Constitution as he could have been if this country had been his birthplace and the home of his ancestors. In his work on Civil Liberty and Self-Government, he has some fine remarks on the power of the institutions of our Anglican race to assimilate new-comers, even to transform them; but when he landed on our shores he had no need of transformation, he was well prepared to love institutional liberty like ours, and to show to others its self-governing capacity.

He was born in Berlin, March 18, 1800, and was old enough to remember the battle of Jena, Napoleon's entrance into Berlin in the autumn of 1806, and the humiliating treaty of Tilsit of the next summer. His childhood and youth were marked by the love of study and of truth; he was fond of gymnastic exercises; he was in training for a future sphere in life, when the return of Napoleon from Elba called him, a boy of only fifteen, into the army. He was at Ligny and at Waterloo; and in the course of this campaign received two wounds. "Seriously wounded," says M. Rolin-Jaecquemyns, in a recent number of his international review, "and knowing no one, the poor boy was transported to Liége, where he found in a respectable family of Belgium, still subsisting, the most disinterested and touching attentions." After this experience of war, on his return to his home and studies, he became acquainted with a somewhat celebrated German of that period, Friedrich L. Jahn, who, in the days of the Tugenbund and the rising of Germany against Napoleon, was patronized by the Prussian government in his gymnastic discipline known by the name of Turnkunst, but who fell under suspicion after the war of liberation, as a friend of advanced political freedom. Lieber, a favorite pupil, was arrested with the gymnastic teacher, and remained in confinement, it is said, about a year. On his release, being forbidden to study at a Prussian university, he repaired to Jena, where he was graduated in 1820. Jena at this time was the resort of a number of students who were disaffected towards the German governments, because they had not fulfilled the expectations of the time when the young and old pressed into the service of "fatherland" against the French. Lieber may perhaps have known Ludwig Sand, a *tête exaltée* of that University, who, in March, 1819, assassinated Kotzebue, as being an agent of Russian despotism. He was a suspected person within the province of the Prussian police, and, as no prospects opened to him in

that kingdom, was led to remove to Dresden. The Greek insurrection having spread in 1821 through the Morea and the islands, he felt an impulse to take part in the movement; and, sailing from Marseilles, spent parts of that year and of 1822 in the struggle for Greek independence. But he was disappointed and discouraged: he felt constrained to give up his Philhellenic plans, and reached Ancona in Italy almost destitute. From Ancona finding his way to Rome, he became acquainted with Niebuhr, the historian, then Prussian ambassador to the Pope, and was taken into his family to assist in the education of his son. In a letter from Niebuhr to his sister-in-law, from which Judge Thayer of Philadelphia, Lieber's intimate friend, has given an extract, the historian thus speaks of the young Philhellene: "A young man, Lieber of Berlin, has arrived here, who went as a volunteer to Greece, and at length returned, partly not to die of hunger, partly because the rascality of the Moreans and their cowardice became insufferable to him. His veracity is beyond suspicion, and his tales fill the hearer with horrors. He is sad and melancholy, because his soul is very noble. He interests and touches us much, and we try to cheer him by kindness. He belongs to the youth of the beautiful time of 1813 [1815], when he fought and was wounded. He is now here without a cent. I shall help him at any rate."

When Niebuhr returned to Germany in the spring of 1823, Lieber visited Prussia once more, only to find that the suspicions against him were still awake. He was arrested and confined at Köpenick, but the intervention of Niebuhr procured his release. Finding that his own country gave him no welcome, he went at once to London, where he supported himself by teaching and correspondence with German journals.

It is hard to believe that the man so sober in his political principles, so little inclined to a fanatical spirit of liberty or to agitation, could ever, even in the effervescence of youthful liberalism, have been regarded with any good reason as a dangerous character in Prussia. It is possible that his varied experience in life, especially his contact with the liberty "ignorantly worshipped" in Greece, and his intercourse with so wise and broad a man as Niebuhr, may have corrected some misjudgments due to the unselfish ardor of his boyhood; but we cannot imagine that there was any ground for the frown of the Prussian government. Had he remained at home, he would have been a healthy, moderate, and weighty member of the liberal party; not a radical, for such was not his nature, but an earnest advocate of constitutional freedom. But what Prussia lost we gained. Among all the exiles that

have found a refuge here, no one has been so great an acquisition. He arrived in this country in the year 1827, settled at Boston, where he set up a swimming-school for his support, and ere long took the supervision of the work entitled "Encyclopædia Americana, on the basis of the seventh edition of the German Conversations-Lexicon, by F. Lieber, assisted by E. Wigglesworth," in thirteen volumes. After the completion of this work, which was finished in 1833, we find him engaged in New York in a translation of De Beaumont and De Tocqueville on the Penitentiary system of the United States, and then in Philadelphia in preparing a plan of education for Girard College. In 1835 he received the appointment of Professor of History and Political Economy in the College of South Carolina. The middle of his life was spent at this post, and here his most important works were written. During his residence at Columbia, the questions which agitated the country grew in seriousness, and threw dark shadows upon the future. He felt the solemnity of the crisis: his principles were immovably fixed against disunion, and he was in a position to know the wishes and plans of the leaders of Southern opinion. In January, 1850, having had in a meeting of the Faculty of his College — as it would seem — a conversation on the possibility of disunion, he addressed a letter to the gentleman with whom he had conversed, from which we extract two or three sentences: "No peaceful separation is possible in the nature of things, even though both parties should desire it." "A war between the North and the South would be one of the bitterest ever recorded." "In less than twenty years we would have again an abolition party in the northern parts of the southern Union; for anti-slavery is not an artificial thing. It lies in the nature of civilization and the course of history. Slavery is a deciduous institution, which always falls at a certain time, as the first teeth are absorbed and give way to the second and permanent teeth." "The people of the South would become protectionists in the highest degree, and go through all the phases of that unhappy error." "If the South now complains of unsurrendered fugitives, they would then escape by shoals; and no exertion would be adequate to watch the frontier such as it then would be." "A weight of opinion would press upon us, which would be heavy indeed, for the world is against slavery." *

Six years and a little more after this sagacious and characteristic letter was written, Dr. Lieber received an invitation to the Professorship of Constitutional History and Public Law in Columbia College,

* Published in the "New York Evening Post" of January 31, 1873.

New York, and became subsequently Professor of Political Science in the Law School of the same institution. That this appointment was acceptable to him, that he regarded it as a refuge from trouble in the future, as well as a highly honorable position in itself, we have reason to believe. For, although he never belonged to the abolitionist party, every one knew that he could not love the institutions of slavery, and the spirit of disunion was every year gathering fresh strength, as he foresaw clearly. For words written a quarter of a century before, he was, it is said, in or about 1856, brought to the bar of a savage press and mob, such as reigned in Southern towns. He went to New York at the height of his reputation as the first writer on political and social science in the country. Three years before he changed his home, he published his "Civil Liberty and Self-Government," one of his wisest and most praised works. In the city of New York, surrounded by friends who respected and honored him, he discharged his duties in the academical department of Columbia College, and also lectured in the Law School on the doctrine of rights and on international law. In a few years the war broke out, in which as a writer, a member of the Union League, and by every influence within his reach, he gave the most ardent support to the side of Union and freedom. The war called forth one production of his pen, small in extent, but much labored and full of practical wisdom. We refer to the "Instructions for the Government of Armies of the United States in the Field," which received the warmest plaudits from European publicists. One of them, M. Rolin-Jaecquemyns, in remarking that Lieber's influence was not confined to mere theory, says: "Pour n'en rappeler qu'un exemple encore récent et connu de tous, nous citerons ces fameuses '*Instructions*,' . . . si souvent invoquées en Europe, surtout depuis la dernière guerre, comme une des plus heureuses tentatives de conciliation entre ce que permet la nécessité de la guerre et ce que défend l'humanité." And Dr. Bluntschli has printed the "Instructions" entire at the end of his "Modernes Völkerrecht," and in the introduction gives this war-code as an example of what one State can do in the advancement of the general law of nations. "During the American civil war," he adds, "and in April, 1863, the 'Instructions for the Government of the Armies of the United States in the Field' appeared, which is to be regarded as the very first codification of the laws of war, in wars upon the land. This was sketched by one of the most respected jurists and political philosophers of America, Professor Lieber; was approved by a commission of officers, and accepted by Mr. Lincoln, President of the United States. . . . These 'Instructions' are much more extensive and complete than

the regulations of war in use in most European countries. . . . The States of Europe cannot in this point remain behind the American pattern, without exposing themselves to the mortifying judgment of public opinion, that in the development of the law of nations they keep themselves in the rear of the progress of civilized humanity."

The war came to an end, and left Dr. Lieber as busy as ever in his lectures to his classes, his occasional writings and correspondence. When he began the last work of his life, "The Rise of the Constitution," we know not; but it is a very interesting fact that his last touches — leaving it, as we understand, in a finished or almost finished state — were given on the last day of his life. He was ailing, without being aware that he had any serious malady; and his wife had left the room to provide something for his comfort, when on returning to the chamber she found him already gone. He had died of a disease of the heart. It was on the 2d of October, 1872, on or near the day when his lectures for the year were to begin, at the age of seventy-two years and somewhat more than a half, that he was called away. He died in the Christian faith, a communicant in the Episcopal Church.

In estimating Dr. Lieber's merits as a writer and thinker on political and social questions, this strikes us first of all, that he had a practical education fitting him for his chosen science. Few men have had such advantages of living — at great expense of comfort, it is true — under diverse institutions. He could remember the prostration of Prussia during the domination of Napoleon, and the reviving patriotism, which seized first on young minds, after the disastrous Russian expedition. He was a witness to the reactionary movements in Germany, and to the broken or deferred promises of constitutional liberty. He became a refugee from his fatherland, only to find in the Greece of his imagination a people morally and by imperfect culture unfitted for freedom. He saw the effete and crumbling tyranny of the ecclesiastical state. He learned what English liberty was by a long residence in that country. He made the United States his final home, and became thoroughly, even admiringly, attached to the Constitution. No native citizen perhaps appreciated more fully than he the wisdom of the founders of the American "Bundestaat." And, finally, in this Union he had rare opportunities to compare the capacities for self-government of States under the curse of slavery and of those which were true to the American idea. He was in these ways aided in becoming one of the most practical of political writers, not at all to the result of rejecting theory, but in such a sense that he looked at theory and at practical problems both. His "Civil Liberty and Self-Government" may be said

to be a constant protest against the French idea of liberty; and perhaps no writer in English has so well developed the nature and value of institutions, or has shown so ably the amount of struggle necessary for winning one position of free self-government after another, as he has in this work.*

Dr. Lieber thus united in a rare degree practical and theoretical politics, and for this balance of mind his many-sided life fitted him; but he owed it to his native qualities also, to the value which he put on history and statistics, to the leaning which he felt towards the observation of concrete social problems, to the union, in short, of the qualities of the Anglo-Saxon and of the German mind, that he reached a high degree of political wisdom. The same happy commingling of qualities helped his naturally clear-sighted mind to attain to a higher degree of political sagacity than most men can reach. He saw farther into our institutions and into the evils which threatened them than most native politicians, for he had three guides assisting his foresight, while they generally have but one: he had history, general principles, and immediate observation.

Dr. Lieber showed this happy wisdom, so superior to mere political philosophy, in the ethical qualities of his nature. M. Rolin-Jaecquemyns tells us that his motto in his letters was "no right without its duties, no duty without its rights." His "Political Ethics" (1838, 1839) looks at the State in the first part, and the civic duties of men in the second; but the basis of the whole, like that of Trendelenburg's "Naturrecht," is laid in moral convictions. Throughout the work the conception of a perfect citizen seems to be the leading idea, of a person who has duties in proportion to the greatness of his rights. Dr. Lieber was the first, if we are not in an error, to introduce into the English language the word *jural* as distinguished from moral. A friendly critic of his life and character in "The Nation" describes this work as a "storehouse of political wisdom," and "as distinguished for its profoundness, originality, and its exhaustive treatment of one of the most difficult of subjects." "Judge Story commended it for its sound common sense, varied learning, and profound views of government." "The Legal and Political Hermeneutics," a smaller work, originally

* The author of the present sketch, believing that American youths were in danger of falling into an empty, abstract theory of rights and of freedom resembling the French, used this book in his classes soon after it appeared, for the very purpose of counteracting this tendency, and found that it had a decided influence in favor of correctness of political thought.

intended as a chapter of the "Political Ethics," and bearing the second title of "The Principles of Interpretation and Construction in Law and Politics," has also received high commendation from so eminent a jurist as Professor Greenleaf.

The same writer in "The Nation" says of Dr. Lieber as a writer that "he was lucid and axiomatic, but lacked constructiveness, or the power of judiciously arranging and treating a subject." Perhaps he failed in method, and in not giving enough attention to his philosophical basis; perhaps we may find here and there somewhat of unnecessary copiousness; his style, too, is occasionally somewhat pedantic: but these are slight faults compared with the admirable contents of his works. He never had any thing to say without showing that his mind was a treasury of the wisest thoughts, of rich and apt illustrations, of views which, whether they rebuked reigning tendencies to evil or showed the excellence of the Anglican idea of freedom, commended themselves to all, old and young; so that no one, however advanced in political studies, could come away from his writings without benefit. His "Political Ethics" never went beyond the first edition. Yet this was not owing to its style and character so much as to want of interest in this country in the science of politics. And among its readers, among those who have been forward to speak of its excellences, have been some of the best thinkers and the ablest men in this country.

Dr. Lieber was the author of a large number of works, many of which were political essays of small compass. A list of them may be found in Allibone. Besides those which have been mentioned in the course of this sketch, including his as yet unpublished "Rise of the Constitution," we name here first what may be called occasional works, out of his line of peculiar studies, as his "Journal in Greece" (Leipzig, 1823); "The Translation of Feuerbach's Account of Caspar Hauser;" his "Plan of Education for Girard College;" "Letters of a Gentleman on a Trip to Niagara;" "Reminiscences of B. G. Niebuhr," written at Rome, it is said, but published long afterwards; "Great Events described by Great Historians;" "The Character of the Gentleman;" "The Study of Latin and Greek, as Elements of Education;" "Laura Bridgman's Vocal Sounds;" and his Humboldt Speech at Central Park, September 4, 1869. Several of these were reprinted, or translated and printed in Europe. Next, among the minor works which relate to his especial field of study, we mention his "Origin and Development of the First Elements of Civilization;" "Essays on Property and Labor;" "The Laws of Property;" "Penal Laws, and the Penitentiary System;" "On Prison Discipline;" "The Relation between Education and

Crime;" "The Pardoning Power;" "International Copyright;" "Anglican and Gallican Liberty," translated into German by Mittermaier; "On the Post-Office and Post-Office Reform;" "On the Independence of the Judiciary;" "On Two Houses of Legislature;" "On Guerilla Parties;" and "On Nationalism," a fragment. He wrote more or less for the press, and had friendly correspondence with European publicists. M. Rolin-Jaecquemyns says of him, that when the "Revue de Droit International" was founded, Lieber was brought into connection with him through Laboulaye and Bluntschli; and that a free interchange of thought between the two followed, which gave him an opportunity to know the character and individuality of his friend, although they never saw one another. "His attention was especially fixed," says this gentleman, "in these later times on international law, on the future of this science, on the practical sanctions to be given to it. While he applauded the successes of Germany, his fatherland, he did not desire for it an exclusive empire; and he vividly appreciated the advantage which should result from the pacific rivalry of some great nations."

We thank Germany for her step-motherly treatment of a son of hers, who, as he came here for refuge, brought hither, with no fanatical hostility to the land which he left, her stores of learning, and engrafted them on Anglo-Saxon political wisdom.

The severe training given by the Military Academy at West Point makes such an exception to our usual education that it has sometimes been stigmatized as "monastic." It is as if a piece of the stern, silent discipline, so over-developed in Europe, had been transplanted to a country whose discipline comes only through much arguing and voting. The very fact that such training is an exception, and almost in opposition to the prevailing one, gives mark and power to those who have been subjected to it. Their rigid obedience, their directness in speech and act, and their concentration of thought, carried sometimes even to narrowness, attract notice among a people who possess these qualities, not in their simple form, but complicated with qualities antagonistic.

And so it has come about that an establishment insignificant in size, and hampered by conditions unfavorable to instruction, has nevertheless sent out a great number of notable men, — notable in the sense of being useful and of having authority.

A very striking example was in George Gordon Meade, who died at Philadelphia, November 6, 1872, a Major-General in the regular

army. Some one well said of him that, "had he been trained to the profession of the law, he would have been an eminent jurist." And it is curious to note the effect of rigid military education acting on a mind which was a legal one in its ready spring and its power of weighing evidence. Neither of these qualities was diminished. The readiness remained, but was developed as a faculty carefully limited and ever liable to be called on to "report itself." The judicial power was there, but was used as the judge uses it, to weigh all the evidence; not as the advocate, to sift the testimony on one side. To such inborn traits, there was added, by the studies of the School, a knowledge of the exact sciences, and the rules of a soldier's life. Thus it was that a man, who in the natural course would have risen to the bench, came by the accident of his education to be the leader of armies and the governor of territories.

Born in Cadiz, of American parents, in 1815, Meade was early destined for the army, and graduated at West Point in 1835, as a brevet second lieutenant of artillery. He resigned his commission at the end of a twelvemonth, and for six years was engaged in civil pursuits; much of the time as an engineer. In 1842 he entered the corps of topographical engineers as a second lieutenant, and distinguished himself in that capacity during Taylor's Mexican campaign. He served in the celebrated actions of Palo Alto and Resaca de la Palma, and was brevetted a first lieutenant for gallantry before Monterey. From the close of the Mexican war to the outbreak of the Rebellion, he was an untiring worker in his branch of the service, and did much to build up its great and deserved reputation. It was he who erected the remarkable lighthouses on some of the Florida reefs, the most difficult of access. To him we are indebted for admirable surveys of the northern lakes, and for numerous hydrographic observations. He was still engaged on this work, when the events of the spring of 1861 summoned him — then a captain of engineers — from his head-quarters in Detroit. At that moment he gave characteristic proof of the rigor of his judgment, and of what may be termed his incapacity for being affected by general enthusiasm. At an excited public meeting, he calmly told the people that they could not overcome the crisis either in a short time or by small means, but must make up their minds to vast sacrifices. This cool lecture was ill received; and only as time went on did the hearers learn how wise it was.

Meade was appointed a Brigadier-General of volunteers, and was given command of the second brigade of Pennsylvania Reserves.

Henceforth it is with Virginia and the Army of the Potomac that his name is identified. He was in the thick of the fighting during McClellan's Peninsular Campaign, where he was severely wounded at Glendale, June 30, 1862, while covering the retreat of the army. At South Mountain, he commanded a division of the first corps in its successful attack; and, in the following battle of Antietam, he had his horse shot under him, and received a severe contusion from a canister ball. His division made, near Fredericksburg, the flank attack, which, if strongly supported, might have changed the face of the day. Thus he became an officer of conspicuous merit, and received command of the fifth corps, with which, after the disastrous battle of Chancellorsville, he skilfully covered the army as it recrossed the Rappahannock. When the disagreement of General Hooker with the war department made his displacement inevitable, the choice of his successor, lying between Reynolds and Meade, fell on the latter. And it is a touching circumstance that General Reynolds, by the sacrifice of his life, contributed afterwards to the glory of his near friend and companion in arms. He came, with the advanced guard, to the ridge beyond Gettysburg; and, seeing with his quick military eye that the position must not be given up, he held stubbornly there, and fell at the head of his men. The main body of the army, pushing rapidly on, arrived in time to form on the horseshoe ridge, now celebrated in history. That night, General Meade, accompanied by a captain of engineers, examined in person the whole position, and made his final dispositions. The battle that followed is too familiar to be told again. When night fell after the last day, the flower of the Army of Northern Virginia lay dead on the field, or were gathered as helpless prisoners. There turned the tide of rebellion; and though, as it ebbed, the waves again and again came fiercely back, they each time retreated farther, and at last they were still. General Meade commanded the Army of the Potomac in this crowning battle of the war. Had defeat come of it, on him would have fallen the disgrace; but it was victory, therefore let no one divide his glory!

Nothing shows more clearly the weakness of popular judgment in matters military than the common charge made against the victor, that he failed to capture Lee's army, which was stopped at Williamsport by the rise of the Potomac. Nor was it till the other day — nine years after the event — that this fallacy was laid open by a few simple sentences from the mouth of General Humphreys.* Any beaten

* Address at the Meade Memorial Meeting, November 18, 1872.

army, placed as the Confederates were, can retreat during the night without interruption; and, once in motion, all advantage of speed lies with them. They can destroy bridges and block roads; and, while the main body marches steadily on, a weak rear-guard will suffice to compel the pursuing column to halt, deploy, and lose time. The Union Army arrived before the entrenched position at Williamsport with only a small numerical superiority; and it is safe to say that a force even of two to one would scarcely have availed to carry the lines by assault. All testimony — and it includes that of British officers — is to the effect that the *morale* of the rebel army was unimpaired. And this may well be believed, if we recall its last days, when, at Sailor's Creek and at Farmville, a rear-guard composed of weary, half-starved men, who knew their case was hopeless, faced steadily about, and for a time held back the enemies who crowded from all sides upon them. It may therefore be considered morally certain that any hasty attack on Lee in his position on the Potomac would have ended in a disaster which might have gone far to neutralize the advantage of Gettysburg. General Humphreys, an officer who does not deal in ill-considered rhetoric, closes his critical description thus: "After a careful examination of the subject, so far as I am capable of forming an opinion, I am led to the conclusion that Meade at Gettysburg had a more difficult task than Wellington at Waterloo, and performed it equally well, although he had no Blücher to turn the scale in his favor." He pertinently adds that Wellington, for Waterloo, was loaded with honors and received £200,000 from Parliament. "Meade, who was a Major in the Corps of Engineers, was promoted to the rank of Brigadier-General in the regular army, and was gratified at this mark of approval!"

In the movements that followed this great action, the position of commander of the Army of the Potomac was one of extreme difficulty; because he was expected, with an inadequate force, not only to beat the enemy, but at the same moment to cover Washington. For it is to be noted that Richmond, a place of moderate size, and separated by a vast extent of bad country from any other Southern city, was not to be weighed against Washington, the capital of the nation, full of archives and valuable public buildings, and close to the populous cities of Baltimore and Philadelphia. Therefore the Union Army was, in some sort, compelled to dance attendance on the rebel; as during the singular movement of Lee upon Centerville, by Warrenton, in October, 1863. Meade had then no alternative but to march in all haste parallel to him, endeavoring to cut the head of his column and force

him to battle. This necessity continued nearly to the end of the war, and when the circle of combat had moved as far as Petersburg. In the summer of 1864, the movement of Early, with a moderate force, threatening Washington and Baltimore, was sufficient to compel Grant to detach a corps of infantry and a division of cavalry, in order to cover those places.

The season of 1863 was fated to end in manœuvres only, despite an admirably planned attempt to cross the Rapidan, and surprise the right of the enemy, near a brook called Mine Run. The difficulty of the tortuous and narrow wood-roads, and the inefficiency of certain subordinates, fatally delayed the march of one wing of the army, and rendered a surprise impossible. Stung though he was by a failure which was not his own, Meade at that moment showed a conscientiousness and a spirit of self-sacrifice, which must ever make him dear in the memory of his soldiers. There were not wanting those who urged him to attack at all hazards; warning him that his command would be taken from him, if he seemed to hold back from fighting. But not the prospective downfall of his great reputation could shake his rigid judgment. He made up his mind that an assault was hopeless, and gave the order to withdraw that night. Meade never forgot this sacrifice, nor the criticisms of some who lived in safe places. Amid the horrid carnage of Spottsylvania and Cold Harbor, he one day said bitterly: "Some people thought I would not fight hard enough, because at Mine Run I held the lives of my men dearer than my own glory. I hope they are satisfied *now*."

When Grant was appointed Lieutenant-General of the forces, in place of the singular aulic council, which hitherto had cramped military operations, he was quick to see that the Rebellion could have no end, so long as the strongest hostile army lay within three days' march of Washington. Therefore, while he directed by telegraph all the armies in the field, he accompanied in person the Army of the Potomac. But Meade still commanded it, and, as is needless to explain to military men, the tactical combinations were his alone.

Painfully did his columns struggle through the Wilderness; as the men used to say, "fighting and digging all day, and marching all night." Those that survived to cross the James were confronted by the earthworks of Petersburg, the last stronghold of Lee. There Meade stayed all the winter through, living in the tent that during four years had been his only home. To his officers he gave leaves of absence, but he remained in the midst of his troops, waiting for spring and the chance to strike the last blow.

The second of April, 1865, came, when the sixth corps went over the enemy's works; and Lee, with his army cut in two, yet fighting to the last, retreated westward. Sheridan had gone across country to cut off the retreat, while hard in the rear of the fugitives followed Meade. He was too sick with malarial fever to sit on his horse; but, with his usual quiet determination, he insisted on keeping up with the troops. That day week the remnant of the Army of Northern Virginia, hemmed in between Meade and Sheridan, surrendered, and with it fell the last hope of the rebellion.

Scarcely was he free from the rude trials of war, when he was called to play a series of parts, which, by their novelty and their complex nature, might well have overwhelmed a less able man. First came the noted Fenian raid, which brought him in haste to the Canadian frontier. There he found several thousand men, old soldiers the most of them, organized and just making ready to invade a country with which we were at peace. Meade caused their arms, which were coming by railroad, to be seized; and by this ready device completely paralyzed the movement.

Next he was despatched to be military governor of Georgia and the adjacent States, than which a more trying position can scarcely be conceived. Stigmatized as a satrap by the conquered people, disliked by greedy politicians who called themselves Unionists, and supported by an insufficient force of officers and men, Meade was compelled, not only to fill the duties of his own profession, but also to perform the *rôle* of a territorial governor, with dubious powers, and to act as a constitutional lawyer in unravelling the ill-considered legislation by which Congress sought to re-establish the South. In all these labors he acquitted himself so admirably as to compel the respect even of his bitterest opponents; and it is not too much to say that no other military governor had such a measure of success.

With these vexatious trials his labors ended, and happily he was permitted to enjoy the last few years of his life in quiet, holding the honorable but easy command of the department of the East.

Meade was perhaps the first tactician in the United States Army; that is to say, he had in a high degree the rare power of properly moving large bodies of troops in face of the enemy. A natural talent, developed by his long studies as an engineer, gave him a sort of topographical instinct, so that in circumstances the most difficult — at midnight and midst the woods of Spottsylvania, or in the cypress swamps of the Chickahominy — he carried with him a mental order of battle, and was never at a loss as to the position or direction of a corps.

It is not an easy thing to march a hostile army through the plains of North Germany, or the rolling region of Eastern France, where the guns may go two abreast in the roads, and the columns can take through the fields on either side, and where men and horses can live in plenty off the country. Much more difficult was it to direct the advance of a hundred thousand men, and a train of supply-wagons forty miles long, through a country like Virginia, whose roads were half obliterated cart-tracks, and whose war-trampled soil had long since ceased to furnish food for man or beast. This ill-reputed fighting ground, which had proved the ruin of many of his comrades, was for him a stage on which to show his ability.

General Meade was only fifty-six years old, but had already done the full work of a long life, and there remained nothing to add to the roundness of his character. His was truly a high type, — a gentleman in thought and deed, scorning trickery or meanness; full of the disciplined courage that neither seeks nor avoids danger; firm in purpose, but never boasting or over-hopeful. He was scrupulous in exacting and in rendering obedience; fiery in temperament, but most forgiving and kindly. Especially he had that high trait, the love of children. He would give money to poor families that were in the route of the army, saying, "Those little things make me think of my children at home." So long as it shall be honorable to be a valiant soldier, a firm patriot, and a Christian gentleman, so long will his name be held in honor.

James Hadley, who died at New Haven on the 14th of November, 1872, was born at Fairfield, N.Y., March 30, 1821. His father, who was himself a remarkable man and an eminent teacher, was Professor of Chemistry at that place in the College of Physicians and Surgeons of the Western District, and afterwards at Hobart College, Geneva, N.Y., to which he removed about the time that his third son, the subject of this notice, was old enough to enter college.

His early education was directed by Dr. Chassel, a Scotch clergyman, whose influence in developing the scholarly tastes of his pupil seems to have been great and well directed. Accounts of the early precocity of great scholars often rest on very uncertain tradition, and are justly suspected of being fabulous. In the case of Professor Hadley, however, we have fortunately a memorandum of his early studies, made by his own hand when he was nineteen years old. In the first entry, referring to a time *before he was seven years old*, he speaks of having already gone over Adams's Latin Grammar under his brother's instruction. In 1828 and 1829 (when seven to eight years old), although "out

of school for a whole year, much of the time very sick," he reviewed his Latin Grammar, and read Historia Sacra (140 sections), nine books of the Æneid and all the Bucolics of Virgil, one book of Livy, besides Irving's "Columbus," "Knickerbocker," and "a few other books." The next year we find him reading Tacitus (one book), Télémaque (five books), and most of Hedge's Logic. He began Greek at the age of ten; and before he was fifteen he had read all the Greek in the Græca Majora, with a large amount of Latin (including all of Horace). At twelve we find him studying Whately's Rhetoric, Bonnycastle's Algebra, and Legendre's Geometry (five books). In 1835 he read all Hume's England; and in 1836, all of the Iliad in Greek, besides going through Stuart's Hebrew Grammar and Chrestomathy. Before entering college, he had also studied Spanish, Italian, and German. It is not wonderful, therefore, that when he entered Yale as Junior in 1840 (after one year at Hobart College), he took the foremost place in his class. On graduating, in 1842, he remained a year in New Haven as resident graduate, engaged chiefly in mathematical studies. At this time he made several communications to the "Mathematical Miscellany," published at Cambridge, Mass. During the next two years he studied theology in New Haven. From 1845 until 1848 he was Tutor in Yale College, and from 1848 until 1851 he was Assistant Professor of Greek. In July, 1851, he was chosen to succeed President Woolsey in the Professorship of Greek, which he held until his death in November, 1872. He became an Associate Fellow of this Academy in 1861.

Few scholars have been so fruitful as Professor Hadley in valuable contributions to literary and scientific periodicals, and in papers read before learned societies. His carefully written communications to the American Oriental Society — of which he was President at the time of his death, and one of the chief supports from its foundation — were of great and lasting value. The same is true of his communications to the more recent American Philological Association, in the success of which he always took the most lively interest, as he had been one of the most active among its founders. In fact, wherever the interests of American scholarship were concerned, and especially wherever there was an opportunity of making his own vast stores of learning and experience available to the great body of less fortunate scholars, Professor Hadley was always the foremost man and the most untiring worker. The influence which he exerted in this way on the scholarship of the whole country, elevating its tone by infusing into it his own spirit, and animating it by his own example, is no insignificant part of the service which he has rendered to the cause of learning. In the

same spirit he performed all the duties of his professorship, sparing himself no labor which would be of solid service to his pupils, and often imposing upon himself duties in elementary instruction to which, we suspect, few scholars of his attainments have ever condescended,— work which, whatever may have been the cost in precious time to himself and to science, certainly bore substantial fruit in the future scholarship of his pupils.

Professor Hadley was so thoroughly devoted to the welfare of his college classes, and of the older pupils whom he instructed in the various societies to which he belonged, that he found little time for book-making. Those who were not within the sphere of his personal influence will regret that he has not left more of his wealth of learning in a form in which it can be accessible to scholars generally. His principal book is his "Greek Grammar for Schools and Colleges," published in 1860, the work by which he is most widely known. Although the Grammar professes to be based on the German work of G. Curtius, it shows on every page the scrupulous care and critical sagacity of Professor Hadley. He was no mere translator; but he made his own and reproduced in a new — often in a greatly improved — form the material which he found in the works of his predecessors. The publication of this work made an era in the study of Greek Grammar in this country, and especially it gave an impulse to the more scientific study of Greek Etymology which is so important an element in modern classical scholarship. One of the constant aims of Professor Hadley's scholarship was to exhibit the phenomena of the Greek language in such a manner that they should illustrate and confirm the great truths of the modern science of language. This object has been attained in his Grammar with brilliant success; and it has perhaps never happened before that a scholar has undertaken to write a Greek Grammar who has combined so thorough a knowledge of Greek with so wide a knowledge of comparative philology as Professor Hadley. An abridgment of the Grammar was published in 1869, prepared by the author. He also wrote the "Brief History of the English Language," which forms a most valuable part of the introduction to the latest edition of Webster's Dictionary (published in 1864). A volume of selections from his *Opuscula* is announced for publication in 1873; as is also a volume of lectures on Roman Law, delivered first in 1868 in Yale College, and afterwards in 1871 as a part of the University course of lectures in the Harvard Law School at Cambridge.

Professor Hadley was one of the very few scholars who have widened their knowledge to a surprising extent without even incurring a suspi-

cion of superficiality. In both breadth and depth of Greek scholarship he was confessedly the first man in the country; but we have also the most positive testimony from the highest sources to his proficiency in Mathematics, in Sanskrit, Gothic, Welsh and the other Celtic languages, Hebrew, Arabic, Armenian, and in the principal languages of modern Europe. With this wide range of learning at his command, he never was known to make a positive assertion on any subject which he had not thoroughly mastered; and, when he did not feel full confidence in his command of a subject, he would often in his modesty conceal knowledge on the strength of which many men would have been dogmatic. This gave him, unconsciously to himself, an air of authority whenever he expressed a decided opinion; and his criticisms, even when expressed in the gentlest language, fell with a severity — often in spite of himself — which nothing but solidity of learning could give. Although it was repugnant to the gentleness of his nature to give pain or offence, he yet had reserves of stinging sarcasm for cases (unfortunately too frequent) in which pernicious error was to be refuted or pretentious ignorance rebuked. The rising scholarship of a new country often runs wild, and needs to be constantly curbed and directed, as well as stimulated, by men of the profound learning, the high character, and the plain common sense which distinguished Professor Hadley. This influence, which has been so wisely exerted upon the present generation of American scholars, will be more and more appreciated now that it is withdrawn.

John Torrey, M.D., LL.D., died at New York, on the 10th of March, 1873, in the seventy-seventh year of his age. He has long been the chief of American botanists, and was at his death the oldest, with the exception of the venerable ex-president of the American Academy (Dr. Bigelow), who entered the botanical field several years earlier, but left it to gather the highest honors and more lucrative rewards of the medical profession, about the time when Dr. Torrey determined to devote his life to scientific pursuits.

The latter was of an old New England stock, being, it is thought, a descendant of William Torrey, who emigrated from Combe St. Nicholas, near Chard, in Somersetshire, and settled at Weymouth, Mass., about the year 1640.*

* In some notes furnished by a member of the family, the descent is endeavored to be traced through the eldest of the five sons who survived their parent, namely, Samuel, who came with him from England, became a minister of the gospel, and had the unprecedented honor of preaching three election sermons

His grandfather, John Torrey, with his son, William, removed from Boston to Montreal at the time of the enforcement of the "Boston Port bill." But neither of them was disposed to be a refugee. For the son, then a lad of seventeen years, ran away from Canada to New York, joined his uncle Joseph Torrey, a major of one of the two light infantry regiments of regulars (called Congress's own) which were raised in that city; was made an ensign, and was in the rear-guard of his regiment on the retreat to White Plains; served in it throughout the war with honor, and until at the close he re-entered the city upon "Evacuation Day," when he retired with the rank of captain. Moreover, the father soon followed the son, and became quartermaster of the regiment. Captain Torrey, in 1791, married Margaret Nichols, of New York.

The subject of this biographical notice was the second of the issue of this marriage, and the oldest child who survived to manhood. He was born in New York, on the 15th of August, 1796. He received such education only as the public schools of his native city then afforded, and was also sent for a year to a school in Boston. When he was fifteen or sixteen years old, his father was appointed Fiscal Agent of the State Prison at Greenwich, then a suburban village, to which the family removed.

At this early age he chanced to attract the attention of Amos Eaton, who soon afterwards became a well-known pioneer of natural science, and with whom it may be said that popular instruction in natural history in this country began. He taught young Torrey the structure of flowers and the rudiments of botany, and thus awakened a taste and kindled a zeal which were extinguished only with his pupil's life. This fondness soon extended to mineralogy and chemistry, and probably determined the choice of a profession. In the year 1815, Torrey

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(in 1674, 1683, and 1695), as well as of having three times declined the presidency of Harvard College (after Hoar, after Oakes, and after Rogers). Although educated at the College, he was not a graduate, because he left it in 1650, after three years' residence, just when the term for the A.B. degree was lengthened to four years. The tradition has it, that, "at the prayer-meetings of the students, he was generally invited to make the concluding prayer,"—for which an obvious reason suggests itself,—for "such was his devotion of spirit that, after praying for two hours, the regret was that he did not continue longer." Students of the present day are probably less exacting.

The desire to claim a descent through so eminent a member of the family is natural. But our late venerable associate, Mr. Savage, in his Dictionary of early New England families, states that he could not ascertain that Samuel had any children.

began the study of medicine in the office of the eminent Dr. Wright Post, and in the College of Physicians and Surgeons, in which the then famous Dr. Mitchill and Dr. Hosack were professors of scientific repute; he took his medical degree in 1818; opened an office in his native city, and engaged in the practice of medicine with moderate success, turning the while his abundant leisure to scientific pursuits, especially to botany. In 1817, while yet a medical student, he reported to the Lyceum of Natural History — of which he was one of the founders — his Catalogue of the Plants growing spontaneously within thirty miles of the city of New York, which was published two years later; and he was already, or very soon after, in correspondence with Kurt Sprengel and Sir James Edward Smith abroad, as well as with Elliot, Nuttall, Schweinitz, and other American botanists. Two mineralogical articles were contributed by him to the very first volume of the "American Journal of Science and Arts" (1818–19), and several others appeared a few years later, in this and in other journals.

Elliot's sketch of the Botany of South Carolina and Georgia was at this time in course of publication, and Dr. Torrey planned a counterpart systematic work upon the botany of the Northern States. The result of this was his "Flora of the Northern and Middle Sections of the United States, *i.e.*, north of Virginia," — which was issued in parts, and the first volume concluded in the summer of 1824. In this work Dr. Torrey first developed his remarkable aptitude for descriptive botany, and for the kind of investigation and discrimination, the tact and acumen, which it calls for. Only those few — now, alas! very few — surviving botanists who used this book through the following years can at all appreciate its value and influence. It was the fruit of those few but precious years which, seasoned with pecuniary privation, are in this country not rarely vouchsafed to an investigator, in which to prove his quality before he is haply overwhelmed with professional or professorial labors and duties.

In 1824, the year in which the first volume (or nearly half) of his Flora was published, he married Miss Eliza Robinson Shaw, of New York, and was established at West Point, having been chosen Professor of Chemistry, Mineralogy, and Geology in the United States Military Academy. Three years later he exchanged this chair for that of Chemistry and Botany (practically that of Chemistry only, for Botany had already been allowed to fall out of the medical curriculum in this country) in the College of Physicians and Surgeons, New York, then in Barclay Street. The Flora of the Northern States was never carried further; although a "Compendium," a pocket volume for the

field, containing brief characters of the species which were to have been described in the second volume, along with an abridgment of the contents of the first, was issued in 1826. Moreover, long before Dr. Torrey could find time to go on with the work, he foresaw that the natural system was not much longer to remain, here and in England, an esoteric doctrine, confined to profound botanists, but was destined to come into general use and to change the character of botanical instruction. He was himself the first to apply it in this country in any considerable publication.

The opportunity for this, and for extending his investigations to the great plains and the Rocky Mountains on their western boundary, was furnished by the collections placed in Dr. Torrey's hands by Dr. Edwin James, the botanist of Major Long's expedition in 1820. This expedition skirted the Rocky Mountains belonging to what is now called Colorado Territory, where Dr. James, first and alone, reached the charming alpine vegetation, scaling one of the very highest summits, which from that time and for many years afterward was appropriately named James's Peak; although it is now called Pike's Peak, in honor of General Pike, who long before may have seen, but did not reach it.

As early as the year 1823 Dr. Torrey communicated to the Lyceum of Natural History descriptions of some new species of James's collection, and in 1826 an extended account of all the plants collected, arranged under their natural orders. This is the earliest treatise of the sort in this country, arranged upon the natural system; and with it begins the history of the botany of the Rocky Mountains, if we except a few plants collected early in the century by Lewis and Clark, where they crossed them many degrees farther north, and which are recorded in Pursh's Flora. The next step in the direction he was aiming was made in the year 1831, when he superintended an American reprint of the first edition of Lindley's "Introduction to the Natural System of Botany," and appended a catalogue of the North American genera arranged according to it.

Dr. Torrey took an early and prominent part in the investigation of the United States species of the vast genus *Carex*, which has ever since been a favorite study in this country. His friend, Von Schweinitz, of Bethlehem, Penn., placed in his hands and desired him to edit, during the author's absence in Europe, his Monograph of North American Carices. It was published in the Annals of the New York Lyceum in 1825, much extended, indeed almost wholly rewritten, and so much to Schweinitz's satisfaction that he insisted that this classical

Monograph "should be considered and quoted in all respects as the joint production of Dr. Torrey and himself." Ten or eleven years later, in the succeeding volume of the Annals of the New York Lyceum, appeared Dr. Torrey's elaborate Monograph of the other North American Cyperaceæ, with an appended revision of the Carices, which meanwhile had been immensely increased by the collections of Richardson, Drummond, &c., in British and Arctic America. A full set of these was consigned to his hands for study (along with other important collections), by his friend Sir William Hooker, upon the occasion of a visit which he made to Europe in 1833. But Dr. Torrey generously turned over the Carices to the late Professor Dewey, whose rival Caricography is scattered through forty or fifty volumes of the "American Journal of Science and Arts;" and so had only to sum up the results in this regard, and add a few southern species at the close of his own Monograph of the order.

About this time, namely, in the year 1836, upon the organization of a geological survey of the State of New York upon an extensive plan, Dr. Torrey was appointed Botanist, and was required to prepare a Flora of the State. A laborious undertaking it proved to be, involving a heavy sacrifice of time, and postponing the realization of long-cherished plans. But in 1843, after much discouragement, the Flora of the State of New York, the largest if by no means the most important of Dr. Torrey's works, was completed and published, in two large quarto volumes, with 161 plates. No other State of the Union has produced a Flora to compare with this. The only thing to be regretted is that it interrupted, at a critical period, the prosecution of a far more important work.

Early in his career Dr. Torrey had resolved to undertake a general flora of North America, or at least of the United States, arranged upon the natural system, and had asked Mr. Nuttall to join him, who, however, did not consent. At that time, when little was known of the regions west of the valley of the Mississippi, the ground to be covered and the materials at hand were of comparatively moderate compass; and, in aid of the northern part of it, Sir William Hooker's Flora of British America — founded upon the rich collections of the Arctic explorers, of the Hudson's Bay Company's intelligent officers, and of such hardy and enterprising pioneers as Drummond and Douglas — was already in progress. At the actual inception of the enterprise, the botany of Eastern Texas was opened by Drummond's collections, as well as that of the coast of California by those of Douglas, and afterward those of Nuttall. As they clearly belonged to our own

phyto-geographical province, Texas and California were accordingly annexed botanically before they became so politically.

While the field of botanical operations was thus enlarging, the time which could be devoted to it was restricted. In addition to his chair in the Medical College, Dr. Torrey had felt obliged to accept a similar one at Princeton College, and to all was now added, as we have seen, the onerous post of State Botanist. It was in the year 1836 or 1837 that he invited the writer of this notice — then pursuing botanical studies under his auspices and direction — to become his associate in the Flora of North America. In July and in October, 1838, the first two parts, making half of the first volume, were published. The great need of a full study of the sources and originals of the earlier published species was now apparent; so, during the following year, his associate occupied himself with this work in the principal herbaria of Europe. The remaining half of the first volume appeared in June, 1840. The first part of the second volume followed in 1841; the second in the spring of 1842; and in February, 1843, came the third and the last; for Dr. Torrey's associate was now also immersed in professorial duties, and in the consequent preparation of the works and collections which were necessary to their prosecution.

From that time to the present the scientific exploration of the vast interior of the continent has been actively carried on, and in consequence new plants have poured in year by year in such numbers as to overtask the powers of the few working botanists of the country, nearly all of them weighted with professional engagements. The most they could do has been to put collections into order in special reports, revise here and there a family or a genus monographically, and incorporate new materials into older parts of the fabric, or rough-hew them for portions of the edifice yet to be constructed. In all this Dr. Torrey took a prominent part down almost to the last days of his life. Passing by various detached and scattered articles upon curious new genera and the like, but not forgetting three admirable papers published in the Smithsonian Contributions to Knowledge (Plantæ Fremontianæ, and those on *Batis* and *Darlingtonia*), there is a long series of important, and some of them very extensive, contributions to the reports of government explorations of the western country, — from that of Long's expedition already referred to, in which he first developed his powers, through those of Nicollet, Fremont, and Emory, Sitgreaves, Stansbury, and Marcy, and those contained in the ampler volumes of the Surveys for Pacific Railroad routes, down to that of the Mexican Boundary, the botany of which forms a bulky quarto volume, of much interest.

Even at the last, when he rallied transiently from the fatal attack, he took in hand the manuscript of an elaborate report on the plants collected along our Pacific coast in Admiral Wilkes's celebrated expedition, which he had prepared fully a dozen years ago, and which (except as to the plates) remains still unpublished, through no fault of his. There would have been more to add, perhaps of equal importance, if Dr. Torrey had been as ready to complete and publish, as he was to investigate, annotate, and sketch. Through undue diffidence, and a constant desire for a greater perfection than was at the time attainable, many interesting observations have from time to time been anticipated by other botanists.

All this botanical work, it may be observed, has reference to the Flora of North America, in which, it was hoped, the diverse and separate materials and component parts, which he and others had wrought upon, might some day be brought together in a completed system of American botany. It remains to be seen whether his surviving associate of nearly forty years will be able to complete the edifice. To do this will be to supply the most pressing want of the science, and to raise the fittest monument to Dr. Torrey's memory.

In the estimate of Dr. Torrey's botanical work, it must not be forgotten that it was nearly all done in the intervals of a busy professional life; that he was for more than thirty years an active and distinguished teacher, mainly of chemistry, and in more than one institution at the same time; that he devoted much time and remarkable skill and judgment to the practical applications of chemistry, in which his counsels were constantly sought and too generously given; that when, in 1857, he exchanged a portion, and a few years later the whole, of his professional duties for the office of United States Assayer, these requisitions upon his time became more numerous and urgent.* In addition to the ordinary duties of his office, which he fulfilled to the end with punctilious faithfulness (signing the last of his daily reports upon the very day of his death, and quietly telling his son and assistant that it would not be necessary to bring him any more), he was frequently requested

* It ought to be added that, when the Government Assay Office at New York was established, the Secretary of the Treasury selected Dr. Torrey to be its Superintendent, — which would have given to the establishment the advantage of a scientific head. But Dr. Torrey resolutely declined the less laborious and better paid post, and took in preference one the emoluments of which were much below his worth and the valuable extraneous services he rendered to the Government, — simply because he was unwilling to accept the care and responsibility of treasure.

by the head of the Treasury Department to undertake the solution of difficult problems, especially those relating to counterfeiting, or to take charge of some delicate or confidential commission, the utmost reliance being placed upon his skill, wisdom, and probity.

In two instances these commissions were made personally gratifying, not by pecuniary payment, which, beyond his simple expenses, he did not receive, but by the opportunity they afforded to recruit failing health and to gather floral treasures. Eight years ago he was sent by the Treasury Department to California by way of the Isthmus; and last summer he went again across the continent, and in both cases enjoyed the rare pleasure of viewing in their native soil, and plucking with his own hands, many a flower which he had himself named and described from dried specimens in the herbarium, and in which he felt a kind of paternal interest. Perhaps this interest culminated last summer, when he stood on the flank of the lofty and beautiful snow-clad peak to which a grateful former pupil and ardent explorer, ten years before, gave his name, and gathered charming alpine plants which he had himself named fifty years before, when the botany of the Colorado Rocky Mountains was first opened. That age and fast-failing strength had not dimmed his enjoyment, may be inferred from his remark when, on his return from Florida the previous spring, with a grievous cough allayed, he was rallied for having gone to seek Ponce de Leon's fountain of Youth. "No," said he, "give me the fountain of Old Age. The longer I live, the more I enjoy life." He evidently did so. If never robust, he was rarely ill; and his last sickness brought little suffering and no diminution of his characteristic cheerfulness. To him, indeed, never came the "evil days" of which he could say, "I have no pleasure in them."

Evincing in age much of the ardor and all of the ingenuousness of youth, he enjoyed the society of young men and students, and was helpful to them long after he ceased to teach, — if, indeed, he ever did cease. For, as Emeritus Professor in Columbia College (with which his old Medical School was united), he not only opened his herbarium, but gave some lectures almost every year, and as a trustee of the college for many years he rendered faithful and important service. His large and truly invaluable herbarium, along with a choice botanical library, he several years ago made over to Columbia College, which charges itself with its safe preservation and maintenance.

Dr. Torrey leaves three daughters, a son, who has been appointed United States Assayer in his father's place, and a grandson.

This sketch of Dr. Torrey's public life and works, which it is our main duty to exhibit, would fall short of its object if it did not convey,

however briefly and incidentally, some just idea of what manner of man he was. That he was earnest, indefatigable, and able, it is needless to say. His gifts as a teacher were largely proved and are widely known through a long generation of pupils. As an investigator, he was characterized by a scrupulous accuracy and a remarkable fertility of mind, especially as shown in devising ways and means of research, and perhaps by some excess of caution.

Other biographers will doubtless dwell upon the more personal aspects and characteristics of our distinguished and lamented associate. To them, indeed, may fittingly be left the full delineation and illustration of the traits of a singularly transparent, genial, delicate and conscientious, unselfish character, which beautified and fructified a most industrious and useful life, and won the affection of all who knew him. For one thing, they cannot fail to notice his thorough love of truth for its own sake, and his entire confidence that the legitimate results of scientific inquiry would never be inimical to the Christian religion, which he held with an untroubled faith, and illustrated, most naturally and unpretendingly, in all his life and conversation. In this, as well as in the simplicity of his character, he much resembled Faraday.

Dr. Torrey was an honorary or corresponding member of a goodly number of the scientific societies of Europe, and was naturally connected with all prominent institutions of the kind in this country. He was chosen into the American Academy in the year 1841. He was one of the corporate members of the National Academy at Washington. He presided in his turn over the American Association for the Advancement of Science; and he was twice, for considerable periods, President of the New York Lyceum of Natural History, which was in those days one of the foremost of our scientific societies. It has been said of him that the sole distinction on which he prided himself was his membership in the order of the Cincinnati, the only honor in this country which comes by inheritance.

As to the customary testimonial which the botanist receives from his fellows, it is fortunate that the first attempts were nugatory. Almost in his youth a genus was dedicated to him by his correspondent, Sprengel: this proved to be a *Clerodendron*, misunderstood. A second, proposed by Rafinesque, was founded on an artificial dismemberment of *Cyperus*. The ground was clear, therefore, when, thirty or forty years ago, a new and remarkable evergreen tree was discovered in our own Southern States, which it was at once determined should bear Dr. Torrey's name. More recently a congener was found in the noble forests of California. Another species had already been recognized in Japan, and lately a

fourth in the mountains of Northern China. All four of them have been introduced and are greatly prized as ornamental trees in Europe. So that, all round the world, *Torreya taxifolia*, *Torreya Californica*, *Torreya nucifera*, and *Torreya grandis* — as well as his own important contributions to botany, of which they are a memorial — should keep our associate's memory as green as their own perpetual verdure.

William Starling Sullivant died at his residence in Columbus, Ohio, on the 30th of April ult. In him we lose the most accomplished bryologist which this country has produced; and it can hardly be said that he leaves behind him anywhere a superior.

He was born January 15, 1803, at the little village of Franklinton, then a frontier settlement in the midst of primitive forest, near the site of the present city of Columbus. His father, a Virginian, and a man of marked character, was appointed by Government to survey the lands of that district of the "North Western Territory" which became the central part of the now populous State of Ohio; and he early purchased a large tract of land, bordering on the Scioto River, near by, if not including, the locality which was afterward fixed upon for the State capital.

William, the eldest son, in his boyhood, if he endured some of the privations, yet enjoyed the advantages of this frontier life, in the way of physical training and early self-reliance. But he was sent to school in Kentucky; he received the rudiments of his classical education at the so-called Ohio University at Athens, upon the opening of that seminary; and was afterward transferred to Yale College, where he was graduated in the year 1823. His plans for studying a profession were frustrated by the death of his father in that year. This required him to occupy himself with the care of the family property, then mainly in lands, mills, &c., and demanding much and varied attention. He became surveyor and practical engineer, and indeed took an active part in business down to a recent period. Leisure is hardly to be had in a newly settled country, and least of all by those who have possessions. Mr. Sullivant must have reached the age of nearly thirty years, and, having married early,* was established in his suburban residence, in a rich floral district, before his taste for natural history was at all developed. His brother Joseph, next in age, was already somewhat proficient in botany as well as in conchology and ornithology; and, when in some

* His first wife, Jane Marshall, of Kentucky, was a niece of Chief Justice Marshall. She died a few years after marriage.

way his own interest in the subject was at length excited, he took it up with characteristic determination to know well whatever he undertook to know at all. He collected and carefully studied the plants of the central part of Ohio, made neat sketches of the minuter parts of many of them, especially of the Grasses and Sedges, entered into communication with the leading botanists of the country, and in 1840 he published "A Catalogue of Plants, native or naturalized, in the vicinity of Columbus, Ohio" (pp. 63), to which he added a few pages of valuable notes. His only other direct publication in phænogamous botany is a short article upon three new plants which he had discovered in that district, contributed to the American Journal of Science and the Arts, in the year 1842. The observations which he continued to make were communicated to his correspondents and friends, the authors of the "Flora of North America," then in progress. As soon as the flowering plants of his district had ceased to afford him novelty, he turned to the Mosses, in which he found abundant scientific occupation, of a kind well suited to his bent for patient and close observation, scrupulous accuracy, and nice discrimination. His first publication in his chosen department, the *Musci Alleghanienses*, was accompanied by the specimens themselves of Mosses and Hepaticæ collected in a botanical expedition through the Alleghany Mountains, from Maryland to Georgia, in the summer of 1843 (the writer of this notice being his companion). The specimens were not only critically determined, but exquisitely prepared and mounted, and with letter-press of great perfection; the whole forming two quarto volumes, which well deserve the encomium bestowed by Pritzel in his Thesaurus.* It was not put on sale, but fifty copies were distributed with a free hand among bryologists and others who would appreciate it. †

In 1846 Mr. Sullivant communicated to the American Academy the first part, and in 1849 the second part, of his "Contributions to the Bryology and Hepaticology of North America," which appeared, one in the third, the other in the fourth volume (new series), of the Academy's Memoirs, — each with five plates, from the author's own

* "Huic splendidæ impressæ 292 specierum enumerationi accedit elegantissima speciminum omnium exsiccatorum collectio."

† A tribute is justly due to the memory of the second Mrs. (Eliza G. Wheeler) Sullivant, a lady of rare accomplishments, and, not least, a zealous and acute bryologist, her husband's efficient associate in all his scientific work until her death, of cholera, in 1850 or 1851. Her botanical services are commemorated in *Hypnum Sullivantiæ* of Schimper, a new moss of Ohio.

admirable drawings. These plates were engraved at his own expense, and were generously given to the Academy.

When the second edition of Gray's "Manual of the Botany of the Northern United States" was in preparation, Mr. Sullivant was asked to contribute to it a compendious account of the Musci and Hepaticæ of the region; which he did, in the space of about a hundred pages, generously adding, at his sole charge, eight copper-plates, crowded with illustrations of the details of the genera, — thus enhancing vastly the value of his friend's work, and laying a foundation for the general study of bryology in the United States, which then and thus began.

So excellent are these illustrations, both in plan and execution, that Schimper, then the leading bryologist of the Old World, and a most competent judge, since he has published hundreds of figures in his *Bryologia Europæa*, not only adopted the same plan in his "Synopsis of the European Mosses," but also the very figures themselves (a few of which were, however, originally his own), whenever they would serve his purpose, as was the case with most of them. A separate edition was published of this portion of the Manual, under the title of "The Musci and Hepaticæ of the United States, east of the Mississippi River" (New York, 1856, imperial 8vo), upon thick paper, and with proof-impressions directly from the copper-plates. This exquisite volume was placed on sale at far less than its cost, and copies are now of great rarity and value. It was with regret that the author of the Manual omitted this cryptogamic portion from the ensuing editions, and only with the understanding that a separate *Species Muscorum* or Manual for the Mosses of the whole United States should replace it. This most needful work Mr. Sullivant was just about to prepare for the press.

About the same time that Mr. Sullivant thus gave to American students a text-book for our Mosses, he provided an unequalled series of named specimens for illustrating them. The ample stores which he had collected or acquired, supplemented by those collected by M. Lesquereux (who was associated with him from the year 1848) in a journey through the mountainous parts of the Southern States under his auspices, after critical determination were divided into fifty sets, each of about 360 species or varieties, with printed tickets, title, index, &c., and all except a few copies for gratuitous distribution were generously made over, to be sold at less than cost, for his esteemed associate's benefit, and still more that of the botanists and institutions who could thus acquire them. The title of this classical work and collection is *Musci Boreali-Americani quorum specimina exsiccata ediderunt W. S.*

Sullivant et L. Lesquereux, 1856. Naturally enough, the edition was immediately taken up.

In 1865 it was followed by a new one, or rather a new work, of between five and six hundred numbers, many of them Californian species, the first fruits of Dr. Bolander's researches in that country. The sets of this unequalled collection were disposed of with the same unequalled liberality, and with the sole view of advancing the knowledge of his favorite science. This second edition being exhausted, he recently and in the same spirit aided his friend Mr. Austin, both in the study and in the publication of his extensive *Musci Appalachiani*.

To complete here the account of Mr. Sullivant's bryological labors illustrated by "exsiccati," we may mention his *Musci Cubenses*, named, and the new species described in 1861, from Charles Wright's earlier collections in Cuba, and distributed in sets by the collector. His researches upon later and more extensive collections by Mr. Wright remain in the form of notes and pencil sketches, in which many new species are indicated. The same may be said of an earlier, still unpublished collection, made by Fendler in Venezuela. Another collection, of great extent and interest, which was long ago elaborately prepared for publication, and illustrated by very many exquisite drawings, rests in his portfolios, through delays over which Mr. Sullivant had no control; namely, the Bryology of Rodgers's United States North Pacific Exploring Expedition, of which Charles Wright was botanist. Brief characters of the principal new species were, however, duly published in this as in other departments of the botany of that expedition. It is much to be regretted that the drawings which illustrate them have not yet been engraved and given to the scientific world.

This has fortunately been done in the case of the South Pacific Exploring Expedition, under Commodore Wilkes. For, although the volume containing the Mosses has not even yet been issued by Government, Mr. Sullivant's portion of it was published in a separate edition, in the year 1859. It forms a sumptuous imperial folio, the letter-press having been made up into large pages, and printed on paper which matches the plates, twenty-six in number.

One volume of the Pacific Railroad Reports, *i. e.*, the fourth, contains a paper by Mr. Sullivant, being his account of the Mosses collected in Whipple's Exploration. It consists of only a dozen pages of letter-press, but is illustrated by ten admirable plates of new species.

The *Icones Muscorum*, however, is Mr. Sullivant's crowning work. It consists, as the title indicates, of "Figures and Descriptions of most of those Mosses peculiar to Eastern North America which have not

been heretofore figured," and forms an imperial octavo volume, with 129 copper-plates, published in 1864. The letter-press and the plates (upon which last alone several thousand dollars and immense pains were expended) are simply exquisite and wholly unrivalled; and the scientific character is acknowledged to be worthy of the setting. Within the last few years most of the time which Mr. Sullivant could devote to science has been given to the preparation of a second or supplementary volume of the *Icones*. The plates, it is understood, are completed, the descriptions in a good degree written out, and the vernal months in which his mortal life closed were to have been devoted to the printing. The Manual of the North American Mosses was speedily to follow. He was remarkably young for his years, so that the hopes and expectations in which we were indulging seemed reasonable. But in January, not far from his seventieth birthday, he was prostrated by pneumonia, from the consequences of which, after some seeming convalescence, he died upon the last day of April. He leaves a wife, Mrs. Caroline E. (Sutton) Sullivant, children, grandchildren, and great-grandchildren, to inherit a stainless and honored name, and to cherish a noble memory.

In personal appearance and carriage, no less than in all the traits of an unselfish and well-balanced character, Mr. Sullivant was a fine specimen of a man. He had excellent business talents, and was an exemplary citizen; he had a refined and sure taste, and was an accomplished draughtsman. But, after having illustrated his earlier productions with his own pencil, he found that valuable time was to be gained by employing a trained artist. He discovered in Mr. A. Schrader a hopeful draughtsman; and he educated him to the work, with what excellent results the plates of the *Icones* and of his other works abundantly show. As an investigator he worked deliberately, slowly indeed and not continuously, but perseveringly. Having chosen his particular department, he gave himself undeviatingly to its advancement. His works have laid such a broad and complete foundation for the study of bryology in this country, and are of such recognized importance everywhere, that they must always be of classical authority; in fact, they are likely to remain for a long time unrivalled. Wherever Mosses are studied, his name will be honorably remembered; in this country it should long be remembered with peculiar gratitude.

In accordance with his wishes, his bryological books and his exceedingly rich and important collections and preparations of Mosses are to be consigned to the Gray Herbarium of Harvard University, with a view to their preservation and long-continued usefulness. The remainder of his botanical library, his choice microscopes, and other col-

lections are bequeathed to the State Scientific and Agricultural College, just established at Columbus, and to the Starling Medical College, founded by his uncle, and of which he was himself the Senior Trustee.

Mr. Sullivant was chosen into the American Academy in the year 1845. He received the honorary degree of Doctor of Laws from Gambier College, in his native State. His oldest botanical associates long ago enjoyed the pleasure of bestowing the name of *Sullivantia Ohionis* upon a very rare and interesting, but modest and neat Saxifragaceous plant, which he himself discovered in his native State, on the secluded banks of a tributary of the river which flows by the place where he was born, and where his remains now repose.

William John Macquorn Rankine was born in Edinburgh, Scotland, on the 5th of July, 1820. His early education was acquired partly in the Academy of Ayr and the High School of Glasgow, but mainly, it is said, from his father, during a long confinement from a surgical ailment. On recovering his health, he became, while yet quite young, a student in several of the scientific classes of the University of Edinburgh, having as his instructor in physics Professor James D. Forbes. At the age of eighteen he began the practice of his future profession, civil engineering, under Sir John Macneill, and served three or four years under that eminent master, mainly on engineering works in Ireland. During the next ten years he was employed in Scotland on various works, chiefly railways; and about the beginning of the year 1851 he settled in Glasgow, to practise his profession, in partnership with Mr. John Thomson. In 1855 he was appointed Regius Professor of Civil Engineering and Mechanics in the University of Glasgow, a position which he held the remainder of his life. On the 22d of December, 1872, an attack of paralysis closed an illness of several months, during which he suffered from heart disease, and an affection of the eyes that almost deprived him of sight. His death followed late on the evening of the 24th of December, 1872.

It is impossible in this brief notice to do justice to the scientific labors of Professor Rankine. His contributions to various scientific journals are very numerous, and were begun when he was little more than eighteen years of age. In December, 1838, Professor Forbes presented for him to the Royal Society of Edinburgh a paper on the results of observations with Whewell's anemometer; and for the next thirty-five years there followed an uninterrupted series of papers, admirable in tone, and remarkable for their clearness, precision, and force. Among the most important of these papers are those on Molec-

ular Vortices and the Mechanical Action of Heat, the Transformation of Energy, the Science of Energetics, and on various subjects connected with Naval Architecture.

On assuming his professorship, he gave an introductory lecture on the Harmony of Theory and Practice in Mechanics; a discourse that deserves a wide circulation, as a forcible refutation of the fallacy still too prevalent of an incompatibility between theory and practice.

But the most valuable of Professor Rankine's works are his four Manuals on Applied Mechanics, Civil Engineering, the Steam Engine and other Prime Movers, and Machinery and Mill Work. These treatises constitute an imperishable monument to his memory. They are widely known in this country as well as abroad, and are used as text-books in many of our scientific schools. Their merits are well summed up in a recent notice of Professor Rankine by an eminent engineer, who says: "Rankine's text-books on engineering subjects are by far the most satisfactory that have been published in any country. At the time of their publication they have always been in advance of the professional knowledge of the day, but they possess much greater merits than that of mere novelty. Rankine was peculiarly happy in discriminating between those branches of engineering knowledge which grow from daily experience and those which depend on unchangeable scientific principles. In his books he dealt almost exclusively with the latter, which may, and certainly will, be greatly enlarged, but, so far as they have been established, can never change. Hence his books may become the permanent principle of engineering, — a mine which smaller men may work for many years, rendering his knowledge available by giving it a popular setting of their own. By the bulk of the engineering profession, the books are considered hard reading; but, as engineering education improves, they will more and more be recognized as both wonderfully complete and essentially simple. Rankine, by his education as a practical engineer, was eminently qualified to recognize the problems of which the solution is required in practice; but the large scope of his mind would not allow him to be content with giving merely the solution of those particular cases which most frequently occur in engineering as we now know it. His method is invariably to state the problem in its most general form, to find the general solution, and then to apply this solution to special cases. This method does not render the books easy reading for students, nor does it give the most convenient book of reference for the practical man; but it has produced writings, the value of which is permanent instead of being ephemeral."

Professor Rankine was made a member of the Institution of Civil Engineers in 1843, of the Royal Society of Edinburgh in 1849, of the Philosophical Society of Glasgow in 1852, of the Royal Society of London in 1853, and of this Academy in 1866. The degree of LL.D. was conferred upon him in 1856 by Trinity College, Dublin.

Professor Rankine was of middle stature and of muscular frame, with a frank and cordial bearing; and his noble head, crowned with a profusion of curling brown hair, impressed one as having the stamp of genius. He loved music.

Justus Liebig was born at Darmstadt, on the 13th of May, 1803. He was educated at the Gymnasium in that city; and, after an apprenticeship of ten months to an apothecary, he entered the University of Bonn, and afterward that of Erlangen. At the age of nineteen, he began an investigation of fulminating silver; and, his remarkable promise attracting the attention of the Grand Duke, he was sent by him to Paris, then the centre of scientific investigation. There, through the introduction of Humboldt, he obtained admission to Gay Lussac's laboratory, where he completed his first investigation of fulminic acid. In 1824 he returned home, and was appointed Extraordinary, and two years afterward Ordinary, Professor at Giessen, where he began and where he ended his magnificent scientific career. It would be useless to enumerate his memoirs. For nearly thirty years he poured forth scientific papers of extraordinary brilliancy, novelty, and variety of interest. In inorganic chemistry he did little; but in organic chemistry he was long the leader. He saw early in the history of that branch of science the immense richness and extent of the field to be cultivated, and he worked in it as no single man had worked before him. The list of his published papers includes nearly four hundred separate titles. He so far perfected the methods of organic analysis that an accurate determination of the carbon and hydrogen of an organic body requires hardly an hour's work; and his method, with a few changes, is still in use. With the older processes, Berzelius spent years on the analysis of a few organic acids alone. The laboratory at Giessen now became the leading chemical school in Europe. Liebig had an extraordinary power of drawing out young men, of encouraging them, and of stimulating to the utmost their intellectual powers. He had a remarkable personal magnetism. Three or four times a day he walked through his laboratory, stopping to talk with each student, fixing on him his earnest eyes, and questioning him sharply on his work. His mind teemed with suggestions; he left nothing as he found it. No

work came from that laboratory without the stamp of his genius. His method of instruction was simple. He aimed only at making thorough working chemists; never taught special applications of science, but sent out pupils capable of grappling with any problem which might present itself. After principles, details; after methods, applications. As a lecturer, he was extremely impressive. His lectures were fresh, original essays, based frequently upon work then going on in the laboratory, and the audience "could not choose but hear." In 1838 Liebig was called on by the British Association for the Advancement of Science to prepare a report on agricultural chemistry, and in 1842 came the brilliant work which laid the foundation for scientific agriculture. With all its errors, the work gave an extraordinary stimulus to the torpid agricultural intellect. The old, blindfold groping gave way to enlightened experiment; and we are now reaping the fruits of the seed which Liebig then planted. In 1842 he published his work on Animal Chemistry, full of brilliant thoughts, yet not always sound, and often betraying the author's want of previous thorough training in physiology. Liebig himself felt this want very keenly; and though his work, and the numerous researches made in his laboratory in connection with it, excited very great attention, he never felt satisfied with it, and only the first part of the second edition ever appeared. At a later period, he published works on the "Motions of the Juices in the Animal Body," "Researches on the Nature of Food," and "Letters on Modern Agriculture." His classic Letters on Chemistry have gone through several editions, and are among the best specimens of popular scientific treatises. In 1852, Liebig removed to Munich, accepting an invitation of the King of Bavaria. This was the mistake of his life. His real scientific activity then ceased. His school was abandoned, but he continued to write upon scientific subjects with his usual vigor. As a man, he was full of individuality. His wit was keen; his pen caustic, but not malicious; and in controversy he fought for scientific truth only. We are too near him to judge him without favor. No one of his pupils will ever speak of him but with reverence and affection. To them his loss is a personal one. For the world a great light has gone out.

Adam Sedgwick, who died at Cambridge, in England, on the 27th of January, was born at Dent, in Yorkshire, on the 22d of March, 1785. Entering Trinity College in 1804, he graduated with distinction in 1808, and obtained a fellowship in 1809. Destined like his father for the church, he studied theology, and in 1817 received ordination. But

while devoted to academic pursuits, he had shown such an interest in geological studies that he was in 1818 appointed by the senate to succeed Hailstone as Woodwardian Professor of Geology to the University, a post which, with his fellowship, he held till his death. Thenceforth his energies were chiefly given to the duties of his new office, and to the advancement of the science which it had become his duty to teach. In 1819 he aided in the formation of the Cambridge Philosophical Society, in the Transactions of which appeared, in 1820–21, his earliest contributions to geology, being researches on the crystalline rocks of Cornwall and Devon. These were soon followed by studies of the magnesian limestones of the north of England, which occupied him from 1822 to 1828, and constitute one of the most important contributions to geological science of their time. He also visited Germany for the purpose of studying there the corresponding strata which are intermediate between the coal formation and the Meseozoic, and constitute the series to which Murchison afterwards gave the name of Permian.

It was about this time that Sedgwick became acquainted with Murchison, who, having left the army, was devoting himself as a zealous and successful amateur to the study of geology, and soon became the disciple and fellow-laborer of the Cambridge professor. Together they visited Scotland in 1827, and the eastern Alps in 1829 and 1830; and in 1831 undertook with a common plan, but separately, the great work of investigating the rocks of Wales beneath the old red sandstone. These ancient strata and their equivalents of the continent, at that time almost unstudied, were then included under the common name of the Graywacke series; and to the two investigators just named belongs the honor of having first clearly determined their stratigraphical and paleontological history. The labor of Sedgwick in North Wales soon enabled him to make out a great series of strata, to which he gave the name of Cambrian; while Murchison, at the same time working from the south-east border of Wales, recognized a series to which he gave the name of Silurian, placing it above the Cambrian of Sedgwick. That the lower divisions of this were identical with the upper portions of his Cambrian was soon pointed out by Sedgwick; but the confusion between the two was only cleared up by the discovery that the sections of Murchison were erroneous, he having confounded under the name of Cambrian two series of strata of different ages. The one in Salop was the same with the lower Cambrian of Sedgwick, and really below the base of Murchison's lower Silurian; while the other in South Wales, instead of being, as supposed, beneath it, was really but a repetition of the latter,

and was moreover a continuation of the upper Cambrian of Sedgwick. The long controversy which arose from this mistake, and the painful results to which it led, have been chronicled elsewhere; and no one will probably now deny that much injustice was done to the illustrious professor of Cambridge. It is the more deeply to be regretted from the fact that it caused the withdrawal of Sedgwick, for the last thirty years of his life, from active co-operation with most of his fellow-workers in geology. The results of recent studies both in England and America have, however, served to confirm in all respects the accuracy of the determinations of Sedgwick. His nomenclature, for a time almost set aside, is once more adopted; and it is now recognized that to him belongs the honor of having laid in his Cambrian series the foundations of palæozoic geology.

His immense labor and achievements as a systematizer must not however lead us to overlook his great merit as a philosophical geologist. As opposed to that school which finds an explanation of geological phenomena in convulsions and cataclysms, Sedgwick early maintained the notion of uniform order and succession. He declared that the conception embodied in the name of System, as applied to groups of rocks, was based upon a fallacy, and that the succession of life through geologic time shows that all belongs to one *systema naturæ*.

The immense collections of rocks and organic remains, which had been brought together at Cambridge by Sedgwick and his pupils, had become one of the most complete in the world; and Sedgwick now gave his attention to the preparation of that magnificent work, in two volumes, quarto, entitled "British Palæozoic Rocks and Fossils," which appeared in 1851–54, the joint work of himself and McCoy. This subject continued to engage his attention; and since his death there has appeared a Catalogue of the Cambridge Collection, prepared with the aid of Salter and Morris, with a Preface dictated by Sedgwick himself in the summer of 1872, which shows that to the last he retained his memory and his intellectual vigor. To this great collection the energies of his later years and all his private means were devoted; and the memorial which a grateful generation is about to erect to him is to take the shape of a new building for the Geological Museum at Cambridge.

But it is not only as a geologist that Sedgwick claims our grateful remembrance. His discourse on the Studies of the University of Cambridge, delivered in 1832, and many times since reprinted, remains a monument of the breadth and soundness of his views on education, and

the value both of scientific and literary culture. Endowed with singular eloquence as a lecturer on his favorite science, he inspired in the minds of the successive classes of students, who for fifty years enjoyed his instructions, a rare interest in geology and a personal devotion which was unrivalled. Nor was he less reverenced as a religious teacher; and the announcement of a sermon from Sedgwick always attracted a large audience of admirers at the University. Alike by his learning, his eloquence, his philosophic insight, his rare love of truth, his simplicity, his piety, and the singular personal influence which he exerted on all those who came in contact with him, he was not only a great moral power in the University for more than sixty years, but merits the language of one of his late eulogists, who declares that "the life of Sedgwick has raised the character of the whole people of England."

The last years of his life were rendered painful by deafness, impaired eye-sight, and advancing infirmity. He was, however, able last summer to accomplish his usual residence of a few weeks at Norwich, where his ecclesiastical duties as a canon of the cathedral required his presence, and in October, 1872, writing from Trinity College to a friend in Boston, says: "I am again settled in this grand old College, which has been my chief home since my freshman year, 1804. Since then what mighty changes have been in the moral and political aspects of the world!" In a still more recent note written by his own hand, on receiving the intelligence of our great fire in November last, he expressed his anxiety for the welfare of his Boston correspondent, and his belief that he should not survive till the spring time, but adds, "I await death with a good Christian hope, and send you an old-fashioned offering, — an old man's blessing."

Christopher Hansteen was born on September 26, 1784, in Christiania, Norway, and died at the same place, on April 11, 1873, in the eighty-ninth year of his age. After the foundation of his education had been laid in the Cathedral school of his native city, he entered the University of Copenhagen in 1802, becoming a student, at first of law, and afterwards of mathematics. In 1806 he was appointed teacher of mathematics in the Gymnasium of Fredericksburg, in Zealand. As early as in the year 1807, his interest in the study of Terrestrial Magnetism was excited by the inspection, at Upsala, of a globe, on which was delineated the neighborhood in which the southern magnetic pole was situated. This interest was soon kindled into a flame, which burned brightly to the end of his life; and which, spreading from mind to mind, and from country to country, at length produced, on the call

of Humboldt, a general awakening upon this subject throughout Europe and America.

In 1811 the Royal Danish Academy of Sciences in Copenhagen offered their customary prize for the best answer to this question: "Is it necessary, in order to explain the facts in the earth's magnetism, to suppose more than one magnetic axis in the earth?" In the following year the prize was given to Hansteen. In 1814 he was appointed to the Chair of Astronomy and Applied Mathematics in the University of Christiania, recently founded by Frederick IV. of Norway. In 1819 he published, at the expense of the king, his greatest work, entitled "Untersuchungen über den Magnetismus der Erde," in a quarto volume of 650 pages, illustrated by five copper-plates and an atlas of seven magnetic charts. This book is the rich depository of all the observations which had been made on the elements of the earth's magnetism prior to the date of its publication, and contains a condensed history of the subject for that long period. But this was only preparatory to its principal object, which was a mathematical analysis of all the observations in the light of Euler's theory of magnets. In this way Hansteen labored to test the speculations of Halley as to the existence of four magnetic poles in the earth, and to give a satisfactory answer to the critical problem presented by the Danish Academy of Sciences. After only a portion of the work was written and communicated to the Secretary of the Academy, the prize was won.

The *declination-chart* for 1787, prepared by Hansteen for his Magnetic Atlas, surpassed in accuracy and fulness similar charts already published by Halley, by Mountain and Dodson, and by Churchman. From the convergency of the lines of declination, Hansteen decided in favor of two magnetic poles in the northern and also two in the southern hemisphere. From the secular changes in these lines, he inferred that the northern magnetic poles were moving obliquely towards the east, and those in the south towards the west. Imperfect observations enabled him to calculate *approximately* the period of complete revolution for each pole, and he called attention to this coincidence: that the shortest time in which all the poles will return to the same relative position agreed closely with the period of revolution in the precession of the equinoxes.

No one knew better than Hansteen that the magnetic observations made, in 1768 and 1769, in Northern Asia, by those who were sent there to watch the transit of Venus, reinforced by those collected by Schubert in his journey to Siberia in 1805, were altogether insufficient to mark the exact position of the Asiatic pole of magnetism. By the

liberality of the Norwegian government, he was able himself to make a journey to Siberia, in company with Due and Erman, themselves zealous devotees in the same cause. They left the gate of Berlin, in search of an ideal point in a strange region, on April 25, 1828, and penetrated as far as to Kiachta and Irkutsk. The Russian government offered every facility and encouragement to the undertaking. If Hansteen's journey was less of a pageant and an ovation than that which Humboldt made in 1829, by command of the Emperor of Russia, nevertheless it yielded an abundant harvest in the fields of terrestrial magnetism. The establishment of ten magnetic observatories in the Russian empire, on the recommendation of Humboldt, followed by a cheerful and extensive co-operation throughout the civilized world; the vast mass of observations garnered up at these places, and the results deduced from such ample materials by Gauss, Sabine, Lamont, and many others,—all redound to the honor of Hansteen and Erman, as well as of Humboldt. The immediate effect of Hansteen's journey was the establishment beyond a doubt of the existence of a magnetic pole in Siberia, supplementary to that in British America, and of the biaxial character of the earth's magnetism.

Hansteen's elaborate treatise on Terrestrial Magnetism, to which reference has already been made, discussed the *isoclinic* and *isodynamic* lines, as well as those of *declination;* and his Magnetic Atlas contained maps of dip and intensity, excelled at the present day only so far as the increased number of observations in the arctic and antarctic regions, in the United States of America, and at the numerous magnetic observatories, has supplied more accurate and abundant data. The daily changes in the declination, the influence of the aurora upon it, and the probable dependence upon the sun of the fluctuations in the earth's magnetism, were fully discussed by Hansteen. This work, therefore, must ever remain a noble monument to his industry, learning, and mathematical skill.

After Hansteen's return from Siberia, the Norwegian government furnished the means for building at Christiania a magnetic and meteorological observatory, of which Hansteen was made director. Down to the present moment valuable contributions to science have emanated from it, increasing our knowledge of the earth's magnetism, of the aurora, of shooting stars, and, in general, of astronomy and the physics of the globe. The decennial period, as it is called, in the amplitude of the daily oscillation of the declination-needle, first announced in 1831 by Lamont, from his observations made at the Munich magnetic observatory, of which Sabine found the confirmation in the observations

made at places as remote as Toronto and Hobarton, and which both he and Lamont afterwards extended to the magnetic inclination and intensity, Hansteen reaffirmed as the result of twenty-five years of observation in Christiania. Hansteen, however, changed the period from ten years to 11.33 years. But the coincidence between this period and that of the solar spots, with all its important inferences, still remains. For Wolf, after a full discussion of 23,000 spots, observed between 1749 and 1860, has changed the spot-period from ten years, as originally derived by Schwabe from his own observations at Dessau between 1825 and 1850, to a little over eleven years.

Fortunately for science, Hansteen's most important work was written in the German language. But many of his papers are in his native language, and are published in the journals of his own country, and on this account are not generally accessible to scientific students. Nevertheless, his various contributions to "Schweigger's Journal," to the "Annalen of Poggendorf," and to the "Astronomische Nachrichten," have made his name familiar and his merits widely known. Although terrestrial magnetism gave the dominant key-note to the scientific labors of his life, he published valuable researches in meteorology and astronomy.

In 1837 the Trigonometrical and Topographical Survey of Norway was instituted, and Hansteen was placed at the head of it. In 1856 he completed the fiftieth year of his long term of service as a teacher of science; and his jubilee was duly honored, and a medal was struck in commemoration of the event. In 1861 he retired from active labor. Hansteen was elected in 1863 Foreign Honorary Member of this Academy, in the place left vacant by the death of Biot. His merits were early recognized by the Royal Society of London, and by the Academies of Paris, Berlin, and St. Petersburg.

The name of JOHN STUART MILL is so intimately associated with most of the principal topics of modern philosophical discussion, and with the gravest of open questions, with so many of the weightiest subjects of unsettled theory and practice, that it would be difficult to say for which of his many works his fame is at present the greatest or is most likely to endure. Those subjects in the treatment of which the originality of his position was the least were those in which the qualities most characteristic of him, and for which his writings have been most esteemed, appear in clearest light. Unlike most other great thinkers and masters of dialectics, he did not seek to display what his own invention had contributed to the arguments, or

his observation to the premises, in his discussion of philosophical and practical questions. On the contrary, he seemed to be indifferent to the appearance and reputation of originality, and actuated by a singleness of purpose and a loyalty to the views of his teachers in philosophy and science which were inconsistent with motives of personal vanity. The exercise of his admirably trained dialectical powers doubtless afforded him intrinsic delight, the joy of play, or of spontaneity of power; but it was none the less always subordinated to moral purposes which were clearly defined in his youth, and loyally pursued throughout an active intellectual life for nearly half a century. But his broad practical aims were never allowed, on the other hand, to pervert the integrity and honesty of his intellect. Though an advocate all his life, urging reasons for unpopular measures of reform, and defences of an unpopular philosophy or criticisms of the prevailing one, he was not led, as advocates too frequently are, to the indiscriminate invention and use of bad and good arguments. He weighed his arguments as dispassionately as if his aim had been pure science. Rarely have strength of emotion and purpose and strength of intellect been combined in a thinker with such balance and harmony. The strength of his moral emotions gave him insights or premises which had been overlooked by the previous thinkers whose views he expounded or defended. This advantage over his predecessors was conspicuous in the form he gave to the utilitarian theory of moral principles, and in what was strictly original in his "Principles of Political Economy."

In the latter, the two chief points of originality were, first, his treatment of the subject as a matter of pure abstract science, like geometry; or as an account of the means which are requisite to attain given ends in economics, or the cost needed to procure a given value, without bringing into the discussion the irrelevant practical questions, whether this cost should be incurred, or whether the end were on the whole desirable. These questions really belong to other branches of practical philosophy, — to the sciences of legislation, politics, and morals, to which the principles of political economy stand in the relation of an abstract science to sciences of applied principles and concrete matters. But, secondly, while thus limiting the province of this science, he introduced into it premises from the moral nature of man, by the omission of which previous writers had been led to conclusions in the science of a character gloomy and forbidding. The theory of population of Malthus, as elaborated by Ricardo, seemed to subject the human race to a hopeless necessity of poverty in the masses. Whether the principle of population did really necessitate this conclusion would depend, Mill taught,

on more than the capacity of a soil to support a *maximum* population with the least subsistence needed for the labor of production. The principle applies without qualification to the animal world in general and to savage men; but not to progressive communities of men, in which foresight and prudence, with moral and social aspirations, are forces of more or less influence in checking increase in population, and in improving the condition of the masses. The poorest, the most wretched, are not in the same condition of want in all communities of men. The poorest savage is objectively in a worse condition than the poorest civilized man.

Mill did not oppose the views of his predecessors nor their manner of treatment, as so many other writers had done: he carried out their mode of regarding the science as a physical one, but with a thoroughness which brought to light considerations materially modifying their conclusions. The prospects of mankind are not hopeless, so long as men are capable of aspiration, foresight, and hope; though they may be gloomy enough in view of the slow working of these forces. What these forces have to oppose, however, is not the resistance of an immovable necessity, but only the force of inveterate customs. To the sentimental objection that the laws of political economy are cruel, and therefore not true, Mill humorously replied that he knew of no law more cruel than that of gravity, which would put us all to death, were we not always and vigilantly on our guard against it.

With a full, perhaps a too extreme appreciation of moral forces, as elements in the problems of Political Economy, Mill still treated the science as an abstract one; as a science of conditional propositions, a science applicable to the practical problems of morals and politics, but not in itself treating of them. For example, wars are expensive, and the establishment of a new industry is also an expense which the principles of political economy can estimate; but it does so without deciding whether war or an industry ought under given circumstances to be undertaken.

Moral forces are real agents affecting the future of the human race. As causes of effects, they are calculable forces, and as means to ends are proper subjects of the abstract science of political economy. It was because Mr. Mill believed in "moral causation" (the name he gave to what had indiscriminately been called the doctrine of *necessity* in human volition), and because he himself was powerfully and predominantly actuated throughout his life by high moral considerations, that he gave such emphasis to the moral elements in political economy, and made room for hope — for a sober, rational hope — respecting the

practical conclusions and applications of the science; seeing that hope can subsist with the desire that inspires it, provided the desire is instrumental in effecting what is hoped for. It was because he believed in "moral causation" that he treated political science, in general, in the manner and by the methods of physical philosophy, or as a science of causes and effects. He believed that he himself and his generation would effect much for the future of mankind. His faith was that we live in times in which broad principles of justice, persistently proclaimed, end in carrying the world with them.

His hopefulness, generosity, and courage, and a chivalric, almost romantic disposition in him, seemed to those least acquainted with him inconsistent with the utilitarian philosophy of morals, which he not only professed, but earnestly and even zealously maintained. The "greatest happiness principle" was with him a religious principle, to which every impulse in his nature, high or low, was subordinated. It was for him not only a *test* of rational rules of conduct (which is all that could be, or was, claimed for it in his philosophy of morals), but it became for him a leading motive and sanction of conduct in his theory of life. That other minds differently constituted would be most effectively influenced to the nobility of right conduct by other sanctions and motives, to which the utilitarian principle ought to be regarded as only a remote philosophical test or rational standard, was what he believed and taught. Unlike Bentham, his master in practical philosophy, he felt no contempt for the claims of sentiment, and made no intolerant demand for toleration. He sincerely welcomed intelligent and earnest opposition with a deference due to truth itself, and to a just regard for the diversities in men's minds from differences of education and natural dispositions. These diversities even appeared to him essential to the completeness of the examination which the evidences of truth demand. Opinions positively erroneous, if intelligent and honest, are not without their value, since the progress of truth is a succession of mistakes and corrections. Truth itself, unassailed by erroneous opinion, would soon degenerate into narrowness and error. The errors incident to individuality of mind and character are means, in the attrition of discussion, of keeping the truth bright and untarnished, and even of bringing its purity to light. The human mind cannot afford to forget its past aberrations. These, as well as its true discoveries, are indispensable guides; nor can it ever afford to begin from the starting-point in its search for truth, in accordance with the too confident method of more ambitious philosophers.

Such being his loyalty and generosity, it is not surprising that Mill

obtained a much wider acceptance of utilitarian doctrines, and a more intelligent recognition of their real import, than previous thinkers of his school had secured. He redeemed the word "utility" from the ill repute into which it had fallen, and connected noble conceptions and motives with its philosophical meaning. It is now no longer a synonyme of the ignoble or base, or the name of that quality in conduct, or in any thing which conduces to the satisfaction of desires common to all men. He made it mean clearly the quality in human customs and rules of conduct which conduces to realize conditions and dispositions which for men (though not for swine) are practicable, and are the most desirable; their desirableness being tested by the actual preference which those who possess them have for them as elements in their own happiness. This meaning of utility includes the highest motives in whose satisfaction an individual's happiness can consist, and not the baser ones alone; not even the base ones at all, so far as they obstruct the sources of a greater happiness than they can afford. It is now no longer a paradox to the intelligent student of Mill's philosophy, that he should prefer, as he has avowed, the worst evil which could be inflicted on him against his will, to the pains of a voluntary sophistication of his intellect in respect to the more serious concerns of life.

His method led him to conceal or at least subordinate to his single purpose most of what was original in his discussions of the various philosophical subjects to which he gave his attention. Yet his studies in logic, ethics, psychology, political economy and politics, and even in poetry, are full of valuable and fertile contributions of original thought; and of that kind of service to philosophy which he most valued in such writers as Dr. Brown and Archbishop Whately,— a kind of service which he believed would survive the works of more learned and ambitious thinkers. A thorough preparation for his work, to which his education was directed by his father, realized what is rare in modern times,—a complete command of the art of dialectics; an art which he believed to be of the greatest service in the honest pursuit of truth, though liable to abuse at the hand of the dishonest advocate. His education was like that of an ancient Greek philosopher,—by personal intercourse with other superior thinkers. He felt keenly in his later work, as Plato had, "how much more is to be learned by discussing with a man who can question and answer, than with a book which cannot." That he was not educated at a university, and through the influences of equals and coevals in intellectual and moral development, may account for one serious defect in his powers of observation,—a lack of sensibility to the differences of char-

acter in men, and between the sexes. So far as he did recognize these mental diversities, he prized them for the sake of truth, as he would have prized the addition of a new sense to the means of extending and testing knowledge. But he did not clearly discriminate what was really a reflection, as in a mirror, or a quick anticipation of his own thoughts in other minds, from true and original observations by them. This may be accounted for in part by his philosophical habit, as has been observed, "of always keeping in view mind in the abstract, or men in the aggregate." Though he mingled in the affairs of life with other men, taking part in debates and discussions, private and public, by speech and by writing, all his life, his disposition was still essentially that of a recluse. He remained remote in his intellectual life from the minds and characters of those with whom he contended, though always loyal to those from whom his main doctrines, his education, and inspiration were derived.

A natural consequence of his private education by a philosopher (his father), and by intercourse with superior adult minds, like Bentham and the political economist Say, was that he soon arrived at maturity, and was in full possession of his remarkable powers in early youth, able and eager to exercise them upon the most abtruse and difficult subjects. Annotations to Bentham's "Rationale of Judicial Evidence" was his first publicly acknowledged literary work, performed before he was yet of age; though contributions to the science of botany and other writings were labors of his youth. While still in his youth, before the age of thirty, he advocated reforms in an article in the "Jurist" on "Corporation and Church Property," features of which became acknowledged principles of legislation in Parliament many years later. He lived to see many of the reforms proposed by Bentham enacted as public law, and to take part in Parliament in the furtherance of some of his own political ideas. His courage and hopefulness were not quixotic, but were sustained by real successes. These qualities in his character, though perhaps properly described as romantic, or as springing from an ardent, emotional temperament, were always tempered by his cooler reason and by facts. In more than one division of special study in science and philosophy he mastered facts and details at first hand, or by his own observation; thus training his judgment and powers of imagination to those habits of accuracy so essential in a true education, by which knowledge more extensive, more or less superficial, and necessarily at second hand, can alone be adequately comprehended. He was prepared for writing an important part of his great work on Logic by the study of the principles, requisites, and purposes of

a rational classification in the practical pursuit of botany,—a favorite pastime with him throughout his life. The use to him of this kind of knowledge, as of all other kinds worthy to be called science, was in its bearings on other and wider branches of knowledge. He generalized the principles exhibited in the natural system of botanical classification to their application "to all cases in which mankind are called upon to bring the various parts of any extensive subject into mental co-ordination. They are as much to the point," he adds, "when objects are to be classed for purposes of art or business, as for those of science. The proper arrangement, for example, of a code of laws, depends on the same scientific conditions as the classifications of natural history; nor could there be a better preparatory discipline for that important function than the study of the principles of a natural arrangement, not only in the abstract, but in their actual applications to the class of phenomena for which they were first elaborated, and which are still the best school for learning their use." To rightly divide and define is divine, said Plato; yet it is not an excellence by which the divine is distinguished from a human perfection. It is rather a perfection which is relative to human limits and weaknesses.

The "mastery system" of studying a subject in its facts, and at first hand, was not liable with Mill to degenerate into the mere idiotic pursuit of facts, since the character of his mind was already determined by a strong philosophical bias. Even subjects like the fine arts, which are commonly and properly regarded as affording ends in themselves, or sufficient and worthy motives to study, interested Mill as affording broad principles and influences, extending beyond the immediate and present delight they inspire. In his readings of poetry he looked not merely for beauties or for sympathy, but for principles, causes, and influences; for the relations of it to the times in which it appeared. So wide was the range of his studies and his intellectual sympathies, that no writer has given wiser advice on the much debated subject of education, or advice more satisfactory to all parties, even to the advocates of special studies.

Mr. Mill was a thinker about whose personal character and circumstances of education the student naturally seeks to learn. In such a thinker, these elements of power are instinctively felt to be of prime importance. They explain Mill's later influence at the universities, where, though not personally known, his effect upon the young men of the most active minds, through his principal works, his Political Economy and his System of Logic, became a powerful one, though purely spontaneous; for it did not come in by the normal channels

of the *curriculum*. It was with men of the succeeding generation (as generally happens with great innovators in science and philosophy) that his teachings were destined to be fully appreciated. But his teachings were none of them fundamentally new; or what was new in them was, or appeared to be, subordinate to what he had avowedly borrowed from previous thinkers. He was neither the author of a new system of philosophy, nor the discoverer of a new science. He can hardly be called, in strictness, the advocate even, of any previous doctrine in philosophy or science. It was one of his short-comings that he took for granted more than most of his readers knew. His starting-point was in advance of what most of them knew, and he was thus unintelligible to many of the best minds among his coevals. Starting from what many of them did not know, he completed, carried out, and put into a scientific form in his "System of Logic," and in his "Principles of Political Economy," the views he had adopted from his earlier teachers and from his later studies.

It was through his masterly style of exposition and his skill in dialectics, and by other traits of a personal character to which active and original youth is especially alive, that he secured an unprejudiced hearing for doctrines in philosophy and practice which had almost ceased to have adherents. These doctrines had a century before, from the time of Locke (and before they had made such fearful inroads on existing customs and opinions, as Hume developed from it), become an especially English philosophy; but had almost disappeared through the influence of the Scottish and German reactions against Hume. When his "System of Logic" was published, he stood almost alone in his opinions. The work was not written in exposition or defence of this philosophy, but in accordance with its tenets, which were thus reduced to a proximate application, or to a more determinate or concrete form. A qualified nominalism, thoroughly English, and descended from the English schoolman William of Ockham, was its philosophical basis. He welcomed and introduced to English readers the revival of this philosophy in France, by Auguste Comte, with whom he agreed in many positions, — more especially in those which were not original with Comte. His accordance with Comte can hardly be regarded as one of discipleship, since in most important practical matters Mill dissented from the views of the French philosopher. His real allegiance was to the once prevalent teachings of Locke, and to those of Berkeley, Hume, Brown, Hartley, and his father James Mill.

No modern thinker has striven more faithfully to restore and build upon those speculations of the past, which appeared to him just and true,

or more modestly to exhibit and acknowledge his indebtedness to previous thinkers; yet, by the excellence of his works, this past has fallen to the inheritance of his name and fame. To give scientific form or systematic coherency to views put forth unsystematically by others, was to give soul and life to doctrines which were thus made especially his own. The teachings of Sir John Herschel's celebrated "Discourse on the Study of Natural Philosophy" were generalized by Mill into what is his most original contribution to logic, his theory of induction and of the inductive basis of all real truth. From this theory, important consequences were drawn on the nature and function of syllogistic inference, — consequences from which the philosophical student remounts to the philosophy of experience and the teachings of Hume. From Hume and Brown, again, he derives his theory of causation, which he connects with other elements in his system, and with illustrations in science in a manner which has made the theory peculiarly his own. But it would be out of place in this notice to attempt an analysis of Mill's works. Our task is only to account for his influence.

In politics he belonged to what is called the school of "philosophical radicals," who are, as he defined them, those who in politics follow the common manner of philosophers; who trust neither to tradition nor to intuition for the warrant of political rights and duties, but base the right to power in the State on the ability to govern wisely and justly, and, seeing their country badly governed, seek for the cause of this evil, and for means to remedy it. This cause they found to be in "the Aristocratical Principle," since, in the present imperfect condition of human nature, no governing class would attend to those interests of the many which were in conflict with their own, or could be expected to give to any interests not their own any but a secondary consideration. The remedy for this evil they found in a modified democratic principle; namely, the better ability and disposition of the many to look after their own interests, than any dominant few could have, or would be likely to have, — provided the many, or their representatives, are enlightened enough to know their true interests and how to serve them. The motto of this radicalism was "Enmity to the Aristocratical Principle." From this creed sprung Mill's ardent hostility towards the South in their rebellion against our national government, and his hearty espousal of extreme anti-slavery views.

But a democracy may be tyrannical towards minorities, and, if unchecked, is likely to become so; and, what is worse, is likely to become an unprincipled tyrant, less influenced by considerations of justice or prudence than a governing class would be. This fear made Mill

distrust extreme forms of democracy and government by mere majorities. Accordingly, among his later works, his "Considerations on Representative Government" undertakes to devise checks to the abuse of power by majorities. But it is evident that Mill's greatest trust was in those influences which have given to communities the ability, and thence the power and right, to govern themselves; namely, their intelligence and moral integrity, or that which reduces the necessity of government by force to the fewest functions and occasions. His famous essay on Liberty sought to establish, on grounds of moral principle, restraints of governmental force, in whatever way it might be exercised, whether in the form of public law or of public opinion; neither of which in any form of government is likely to be wiser beyond its proper sphere of duty than those it seeks to control. Government in advanced communities, capable of self-government, should not be of the parental type or degree of power. Coercion, which in itself is an evil, becomes a wrong, where persuasion, rational discussion, and conviction are capable of effecting the same ends, especially when these ends are less urgent than the need of security and self-protection in a community, for which it is the proper duty of government by force to provide. To place government in the hands of those sufficiently intelligent, whose true interests are most affected by it, and to limit its province and its functions as much as possible, leaving as much as possible to non-coercive agencies, was the simple abstract creed of Mill's political philosophy.

The essay on "Liberty" and his later essay on "The Subjection of Women" exhibit the ardent, emotional, enthusiastic, perhaps not the soundest, side of Mr. Mill's mental character and observation of human nature. Yet he cannot be said to have been without much experience in the practical art of government. He was in immediate charge of the "political department," so called, of the East India House for more than twenty years. It was during this period, and in the midst of active employments, that his Logic and Political Economy were written. Both were thought out in the vigor of life and at the summit of his powers. His mind and pen were never idle. At about the age of fifty, he made selections from his occasional short writings for reviews, which were published in two large octavo volumes in the English edition, and make four compact small volumes in the American reprint. These, though occasional writings, had more than a passing interest, since in them, as in all his writings, great and often new principles of criticism are lucidly set forth. In all his writings, his judgments were valued by his readers, not as judgments on occasional

matters by a current or conventional standard, but as tests and illustrations of new standards of criticism, which have a general and enduring interest, especially to the examining minds of youth.

With a tact almost feminine, Mill avoided open war on abstract grounds. The principles of his philosophy were set forth in their applications, and were advocated by bringing them down in application to the common sense or instinctive, unanalyzed judgments of his readers. His conclusions in psychology and on the fundamental principles of philosophy were nowhere systematically set forth. In his Logic, they were rather assumed, and made the setting of his views of the science, than defended on general grounds; though, from his criticisms of adverse views on the principles of Logic, it was sufficiently apparent what his philosophy and psychological doctrines were.

English speaking and reading people had so completely forgotten, or had so obscurely understood the arguments of their greatest thinkers, that the inroad of German speculation had almost overwhelmed the protest of these thinkers against the *a priori* philosophy. English-speaking people are not metaphysical, and Mill respected their prejudice. But when the philosophy of Sir William Hamilton, professing to combine the Scottish and German reactions against Hume with what science had demonstrated as the necessary limits of human knowledge, was about to become the prevalent philosophy of England and America, it was not merely an opportunity, but almost a necessity, for the representative of the greatest English thinkers (himself among the greatest), to re-examine the claims of the *a priori* philosophy, and either to acknowledge the failure of his own attempt to revive the doctrines of his predecessors, or to refute and overthrow their most powerful British antagonist. Accordingly Mill's "Examination of Sir William Hamilton's Philosophy," published in 1865, when he was nearly sixty years old, but in the full vigor and maturity of his powers, was his greatest effort in polemical writing. That the reputation of Sir William Hamilton as a thinker was greatly diminished by this examination cannot be doubted. Nor can it be doubted that the pendulum of philosophical opinion has begun, through Mill's clear expositions and vigorous defence of the Experience philosophy, to move again towards what was a century and a half ago the prevalent English philosophy. That its future movements will be less extreme in either direction, and that the amplitude of its oscillations have continually diminished in the past through the progress of philosophical discussion, were beliefs with which his studies in philosophy and his generous

hopefulness inspired him. Men are still born either Platonists or Aristotelians; but by their education through a more and more free and enlightened discussion, and by progress in the sciences, they are restrained more and more from going to extremes in the directions of their native biases.

In Mill's Examination of Hamilton, and in his last great work, the annotated edition of his father's "Analysis of the Phenomena of the Human Mind," many valuable subsidiary contributions are made to the sciences of logic and psychology. But in all his writings on these subjects his attention was directed to their bearings on the traditional problems and discussions of general philosophy. The modern developments of psychology, as a branch of experimental science, and in connection with physiology, deeply interested him; but they did not engage him in their pursuit, although they promise much towards the solution of unsettled questions. His mental powers were trained for a different though equally important service to science, — the service of clear and distinct thought, the understanding, first of all, of that for which closer observation and the aid of experiment are needed; the precise comprehension and pertinent putting of questions. The progress of science has not yet outgrown the need of guidance by the intellectual arts of logic and method, which are still equal in importance to those of experiment. The imagination of the scientific inquisitor of nature, the fertility of his invention, his ability to frame hypotheses or put pertinent questions, though still generally dependent on his good-sense, and his practical training in experimental science, are susceptible still of furtherance and improvement by the abstract studies of logic and method. Open questions on the psychological conditions of vision are to be settled, Mill thought, only when some one so unfortunate as to be born blind is fortunate enough to be born a philosopher.

Mill has been aptly compared to Locke. Their philosophies were fundamentally the same. Both were "philosophical radicals" and political reformers. "What Locke was to the liberal movements of the seventeenth century, Mr. Mill has more than been to the liberal movement of the nineteenth century." He was born on the 20th of May, 1806, and died on the 8th of May of the current year, having nearly reached the age of sixty-seven. Previous to the brief illness from which he died, he retained unimpaired his mental vigor and industry; and though it may not be said that he lived to see the hopes of his youth fully realized, yet his efforts have met with a degree of success which he did not in later years anticipate. His followers are still few both in politics and in philosophy. So far was he from restoring the doctrines

of his school as the dominant philosophy of England, that, according to his own estimate, "we may still count in England twenty *a priori* or spiritualist philosophers for every partisan of the doctrine of Experience." But it was for the practical applications of this doctrine in politics and in morals, rather than for the theoretical recognition of it in general, that he most earnestly strove; and we should probably find in England and America to-day a much larger proportion, among those holding meditated and deliberate opinions on practical matters, who are in these the disciples of Mill, than can be found among the students of abstract philosophy.

In the death of CHARLES DELAUNAY, the Academy has lost an eminent name from its foreign list, and France one of her most profound and accomplished astronomers. His "Théorie du Mouvement de la Lune" will ever be regarded as a brilliant example of the masterly division of a great problem of mathematical skill and admirable patience. The object of this remarkable work is "to determine, in an analytic form, all the inequalities of the motion of the Moon about the Earth, to quantities of the seventh order inclusive, regarding these two bodies as simple material points, and taking account only of the perturbative action of the Sun, of which the apparent motion round the Earth is supposed to be performed according to the laws of elliptic motion." In carrying the determination to quantities of the seventh order, Delaunay added two orders to those which had previously been considered by Plana, and thereby increased the labor of his task to a vast extent. The first volume of this work, containing about 900 quarto pages, was published in 1860. A second volume was contemplated, but has not yet appeared.

In 1869, M. Delaunay was made director of the Observatory of Paris, in place of M. Leverrier; and he held that post at the time of his death.

Six hundred and fifty-ninth Meeting.

June 10, 1873.—ADJOURNED ANNUAL MEETING.

The PRESIDENT in the chair.

On opening the meeting, the President addressed the Academy as follows:—

GENTLEMEN OF THE ACADEMY,—You have been pleased to confer upon me the honor of presiding over your deliberations, for which I pray you to accept my most earnest acknowledgments.

This distinguished Society takes its date from the moment when the people of Massachusetts first exercised the right of forming a government for themselves, and simultaneously recognized the obligation to encourage all undertakings for the promotion of science, literature, and the arts. The first proof of their fidelity to the pledge was the sanction given to this organization. Since that time, nearly a century has passed away, and many of those most eminent for their proficiency in science and learning in this Commonwealth have been counted among its members. Of these, I cannot overlook the honored portion which has preceded me in the occupation of this chair.

For myself, I can only congratulate you upon the flourishing state in which the Academy now has been transmitted from the hands of my predecessor, and promise for myself only an earnest desire that my relation to it may not be esteemed at its close as wholly unworthy of the bright record which has been made heretofore.

The Treasurer presented his report, which was accepted.

The report of the Rumford Committee was read and accepted. In accordance with its suggestion, it was voted to appropriate: —

$600, to complete Vol. II. of Rumford's works.

$2,000, to publish Vol. III. of Rumford's works.

$500 for the Rumford Medal awarded to Mr. Rutherfurd.

Professor Joseph Lovering presented the report of the Committee of Publication; and, in accordance with its suggestion, it was voted to appropriate $800 for the publications of the Academy.

The President called attention to the loss the Academy had sustained in the death of Christopher Hansteen and M. Verneuil, Foreign Honorary Members, and of John L. Russell, Resident Fellow, of the Academy.

The Librarian presented his report, which was accepted.

It was voted to appropriate: —

For General Expenses	$2,100
For Library	500
For Binding	200

The Recording Secretary exhibited a new form of polarimeter. Remarks on this subject were made by Professor J. P. Cooke.

Professor J. P. Cooke gave a preliminary notice of some determinations of the atomic weight of antimony.

Voted, to adjourn the Stated Meeting in August to September 9.

Six hundred and sixtieth Meeting.

September 9, 1873. — STATED MEETING.

The PRESIDENT in the chair.

The Corresponding Secretary read a letter from R. Clausius, acknowledging his election as Foreign Honorary Member of the Academy.

Professor Joseph Lovering announced that Part 2 of Volume IX. of the Memoirs of the Academy was now ready.

Mr. Edmund Quincy announced that the legacy of one thousand dollars ($1,000) from the late General Sylvanus Thayer had been received.

The President announced the death of Hiram Powers, Associate Fellow, and of Willard Phillips, Resident Fellow, of the Academy.

It was voted that this meeting adjourn, at its close, to the second Tuesday in October.

Mr. S. P. Sharples described some observations on the water of a pond in Melrose.

Six hundred and sixty-first Meeting.

October 14, 1873. — ADJOURNED STATED MEETING.

The PRESIDENT in the chair.

The Corresponding Secretary read a letter from J. S. Sylvester, acknowledging his election as Foreign Honorary Member of the Academy.

The President announced the death of Professor H. J. Clark, Resident Fellow of the Academy.

The Corresponding Secretary suggested that the published form of the Proceedings should be altered; and it was voted to refer this matter to the Secretaries, with full power to act.

Professor Emory Washburn presented a report of the committee appointed to consider the question of expert evidence.

It was voted to accept this report and recommit it, that the committee might prosecute this matter further.

Mr. G. S. Boutwell was appointed a member of this committee, in the place of Judge Gray, who declined to serve.

Mr. E. C. Pickering presented a communication on the applications of Fresnel's formulæ.

Mr. F. W. Putnam exhibited specimens of Myxine, and gave an account of its anatomy. He called special attention to the several stages of development of the eggs noticed in the specimen exhibited.

Six hundred and sixty-second Meeting.

November 12, 1873. — STATED MEETING.

The PRESIDENT in the chair.

The following gentlemen were elected members of the Academy: —

Charles de Rémusat, of Paris, to be a Foreign Honorary Member in Class III., Section 1.

F. Wöhler, of Göttingen, to be a Foreign Honorary Member in Class I., Section 3.

George S. Hillard, of Boston, to be a Resident Fellow in Class III., Section 4.

The Corresponding Secretary read an obituary notice of John Stuart Mill.

Mr. W. A. Rogers presented a communication on the periodic errors of the transit circle.

Six hundred and sixty-third Meeting.

December 9, 1873. — MONTHLY MEETING.

The PRESIDENT in the chair.

Professor Joseph Lovering presented a communication on the proper motion of the fixed stars as determined by the spectroscope.

Professor J. P. Cooke presented a paper entitled "The Vermiculites: their Crystallographic and Chemical Relations to the Micas."

Professor W. H. Pettee, at the request of Professor F. D. Whitney, presented to the Academy a copy of a map of California, and described some measurements of the height of Mount Whitney.

Mr. William Everett presented certain results of investigations into the family names of the Romans, including a new interpretation of *Romans* xvi. 23.

Six hundred and sixty-fourth Meeting.

January 13, 1874. — MONTHLY MEETING.

The PRESIDENT in the chair.

Professor John Trowbridge was appointed Secretary *pro tem.*

The President alluded in a feeling manner to the loss which the Academy had sustained in the death of Professor Louis Agassiz.

The deaths of Carl Friedrich Naumann and Auguste de la Rive, Foreign Honorary Members, were also announced to the Academy.

It was moved by Professor Asa Gray that Doctor Morrill Wyman be invited to prepare a memoir of Professor Treadwell, to be published in the Proceedings.

Professor J. P. Cooke presented a paper on the optical properties of micas, supplementary to that presented at the last meeting.

Professor Joseph Lovering also presented a paper supplementary to that which he read at the last meeting, on Huggins's results on the motions of the stars.

Professor John Trowbridge presented a paper on a method of freeing a magnetic bar from the directive influence of the earth's magnetism.

Mr. S. P. Sharples made some remarks on certain crystals of zinc, formed on the plates of the thermo-battery of Mr. Moses G. Farmer.

Six hundred and sixty-fifth Meeting.

January 28, 1874. — STATED MEETING.

The PRESIDENT in the chair.

The Corresponding Secretary read a letter from Professor Wöhler, of Göttingen, acknowledging his election as Foreign Honorary Member of the Academy.

The following gentlemen were elected members of the Academy: —

Professor George Gabriel Stokes, of Cambridge, to be a Foreign Honorary Member in Class I., Section 3.

Professor Francesco Brioschi, of Milan, to be a Foreign Honorary Member in Class I., Section 1.

Right Honorable William Ewart Gladstone, of London, to be a Foreign Honorary Member in Class III., Section 3.

Mr. Charles Darwin, of Beckenham, to be a Foreign Honorary Member in Class II., Section 1.

Professor George Lincoln Goodall, of Cambridge, to be a Resident Fellow in Class II., Section 2.

It was voted to authorize the additional expenditure of five hundred dollars ($500) for the publications of the Academy.

Mr. F. W. Putnam presented by title a paper on the "Geology of Martha's Vineyard," by Professor N. S. Shaler.

Professor A. Gray presented a paper by Dr. W. G. Farlow, entitled "An Asexual Growth from the Prothallus of Pteris serrulata."

Mr. F. W. Putnam exhibited a transfer of the hieroglyphics on an Egyptian stone in the possession of the Peabody Academy of Science.

Voted, to adjourn this meeting at its close to the second Tuesday in February.

Professor J. P. Cooke presented to the Academy a copy of his work on the "New Chemistry."

Six hundred and sixty-sixth Meeting.

February 10, 1874. — ADJOURNED STATED MEETING.

The PRESIDENT in the Chair.

Professor T. Sterry Hunt made some remarks upon the artificial production of stone.

Mr. Scudder moved that the Council be authorized to memorialize the Legislature on the subject of a new geological survey of the State. On the motion of Professor A. Gray, it was voted that this motion be laid upon the table, to be taken up at the next meeting.

Professor J. P. Cooke called the attention of the Academy to a late corroboration of points in his investigation upon micas.

Voted, to adjourn this meeting to the second Tuesday in March.

Six hundred and sixty-seventh Meeting.

March 10, 1874. — ADJOURNED STATED MEETING.

The Academy met at the house of the President, Honorable Charles Francis Adams.

The PRESIDENT in the chair.

The President announced the deaths of Ira Perley and John Bachman, Associate Fellows, also of Professor Quetelet, of Brussels, Baron Louis and J. Victor Poncelet, of Paris, Foreign Honorary Members.

The President read a letter from Right Honorable W. E. Gladstone, acknowledging his election as Foreign Honorary Member of the Academy.

The Corresponding Secretary stated to the Academy that he had received a letter from Sir William Thomson, acknowledging his election as Foreign Honorary Member.

The Rumford Medals, awarded at the Annual Meeting to Lewis M. Rutherfurd, of New York, were then delivered to the President by the Chairman of the Rumford Committee, with the following words: —

In their last Annual Report, the Rumford Committee recommended that the Rumford Medals for this year should be awarded to Lewis M. Rutherfurd, of New York, for his improvements in the processes and methods of Astronomical Photography. This recommendation was made after long and cautious deliberation, and after a full examination of Mr. Rutherfurd's work by the sub-committee to whom this duty was intrusted. Moreover, the recommendation was made by unanimous vote, and confirmed by a second vote at a subsequent meeting, according to the custom of the Committee. At the last Annual Meeting of the Academy, the recommendation of the Committee received its formal sanction, and the medals were awarded. The Committee have accordingly caused to be struck, at the United States Mint at Philadelphia, from the Rumford dies, a medal of gold, duplicated by one in silver, according to the express direction of Count Rumford; and, as Chairman of the Committee, I have now, Mr. President, the honor to deliver these medals to you, that they may be formally presented to our distinguished Associate, who has done so much to advance astronomy, by applying the beautiful processes of photography to record celestial phenomena.

In presenting the medals, the President said: —

More than three-fourths of a century has passed away since one of the most original characters ever formed upon the soil of Massachusetts established the trust in this Academy, out of which I am this day called to dispense a reward of honor.

Benjamin Thompson was essentially the architect of his own fortunes. His peculiar talents fixed upon him the attention of one of the Princes of Bavaria, and secured his support. In acknowledgment of the high services rendered, Thompson was honored with rank, and received a title as Count Rumford. But such a dignity would never have saved him from oblivion, if he had not fortified it by more memorable devotion to science. Not particularly fitted for political or even social experiments, his nature propelled him to aim at objects not less elevated, though in a different sphere. He addressed his mind to the study and observation of those great phenomena in the universe which are perpetually affording to those who diligently watch them new methods of advancing the progress of mankind. Of these, he selected more particularly the marvellous principles of light and heat, which vivify the creation. He thought, and justly thought, that, old as it was, a great deal more was to be learned of its motive powers, and of their application to practical ends on this globe, than was known down to his time.

After many labors of experimental analysis carried on in person, with more or less of permanent beneficial result, finding himself drawing to his end, he seems to have become so profoundly penetrated by the conviction of the importance of prosecuting this line of investigation in all future time, that it prompted him to devote a considerable share of his personal earnings to the establishment of permanent endowments to encourage the work on both sides of the Atlantic. The purpose of stimulating the ardor for future research in the same path was indicated by his instituting a method of holding out to successful laborers a prospect of rewards, to be distributed under the direction of Scientific Institutions known to him in Great Britain and America at that time, as of well established character. These rewards, though not without material value in themselves, were yet expected to derive their chief importance as publicly conferring upon the winners the honor of receiving, from the most competent authority known in the land, a distinct public confirmation of the value of any discovery or invention connected with light or heat, that might be adjudged to be promotive of benefit to mankind.

Neither was the donor at all mistaken in his prognostication of the progress likely to be made in this noble field of investigation. Already, and within the limits of the first century since his trust was made, the results arrived at have infinitely exceeded the utmost limits of his imagination. Even before his own decease, the mind of Fulton had become big with the grand conception of the application of heat to motion, — an idea which is gradually changing the international relations of the entire globe we inhabit. Not many years after, Morse divined the equally grand project of applying the agent of electricity to the immediate intercommunication of language all over the world. Next in order came the discovery of the application of light to the accurate delineation of all material objects. The advance yet making in this latest and most useful field of labor would alone fully establish the accuracy of foresight of the founder of this trust. It is precisely in connection with this latest step that we have been called upon to pass judgment upon an improved process which has been regularly submitted to the examination of a competent Committee of the Academy.

I may be permitted, Gentlemen of the Academy, to remind you that the application of photography as a method of astronomical observation, like the electro-chronographic method of measuring small intervals of time, is essentially American in its origin and development. On the 23d of October, 1847, the Messrs. Bond of Cambridge, assisted by Mr.

Whipple, a photographer of Boston, took the first recorded photograph of the Moon.

It is scarcely necessary to say that this first attempt was not a great success, for then the art of photography was in its infancy. But it was by no means a failure, and it at least proved that pictures of the Moon could be taken, and gave a stimulus to further experiments. The subject was afterwards taken up in England by Mr. Warren de la Rue. To avoid the difficulties arising from the imperfection of refracting telescopes, which do not bring the visual and chemical rays to the same focus, Mr. de la Rue employed a reflecting telescope; and with this instrument tolerably good results were obtained.

Professor Henry Draper, of New York, employed the same method, using a silvered glass reflector constructed by his own hands, and succeeded, it is believed, better than either of his predecessors. At this period in the history of the application of photography to Astronomy, Mr. Rutherfurd began his work. He also at first worked with silvered reflectors, but after three months' trial abandoned them, and devoted himself to the improvement of the refracting telescope. This he accomplished in his earlier attempts by changing the curvatures of the lenses composing the objective of the telescope, so that the compound lens should give images of the requisite photographic sharpness of definition. He subsequently accomplished the same object by using an additional lens placed in front of the objective, and termed a correcting lens. A great advantage of this method lay in the fact that, by simply removing the correcting lens, the telescope could again be made available for the ordinary methods of direct visual observation. With a telescope so corrected, he obtained the magnificent pictures of the Moon now so generally known and admired both in Europe and in this country, — pictures which have not yet been equalled by those of any other astronomer. He also succeeded in obtaining beautiful stereographs of the Moon, a feat which in Europe had been pronounced impracticable. This he accomplished by taking the two photographs of the Moon when in two different positions in her orbit, and when these pictures combined give the most perfect stereoscopic relief. Up to that time, stereographs of the Moon had been taken only from plaster models. Having perfected the photographic telescope, Mr. Rutherfurd turned his attention to stellar photography, and here his higher scientific work begins. After many trials, he succeeded in obtaining satisfactory pictures of groups of stars, embracing all those in the field of the telescope, down to stars of the eighth or ninth magnitude. Thus the group of the Pleiades afforded him a plate with 175 stars.

His next care was to ascertain that the collodion film on the glass underwent no change from shrinking or from hygroscopic moisture. This fortunately proving to be the case, he proceeded to devise an elaborate micrometric apparatus, by which the relative distances and angular positions of the stars upon a plate could be precisely measured. With this apparatus, a vast number of measurements have been made, for the results of which astronomers will look with impatience. The plates of the Pleiades have been fully discussed by Dr. Gould, and the work is now, I believe, nearly ready for publication. You will thus perceive that Mr. Rutherfurd is the founder of a new astronomical method of measuring and of recording the positions of stars in groups and clusters, by which an enormous amount of labor in observation may be saved. On a single good night for observation — in our climate there are perhaps three in a year — a sufficient number of plates may be taken to occupy the time of a whole corps of assistants for months, in the subsequent work of micrometric measurement and reduction. The German astronomer, Bessel, spent several years on the group of the Pleiades alone. The whole work of mere observation can now be done in a few minutes. It is true that the micrometric measures which follow are tedious; but they may be executed at any time, are independent of weather, and require no extraordinary skill, only patient labor. The absolute places of the stars in a cluster are not given by this method. The right ascension and declination of at least one star in the group must be determined by the ordinary methods of observation. The old method and the new are thus mutually dependent.

Such being the nature of the invention which has been brought to the notice of the Academy, it has been the judgment of the Committee that the case was one coming clearly within the provisions of the trust created by Count Rumford, and consequently that the medals prescribed by him for such occasions should be awarded to the inventor, Mr. Rutherfurd.

And now the moment has arrived when it becomes my agreeable duty, on behalf of the Academy, to present to you, Professor Gibbs, as the chosen representative of the inventor now absent from the country, the great gold medal and its counterpart in silver, specified by the donor as prizes to be awarded in cases of positive advance in this path of science. I pray you to offer to him our fervent congratulations on his success, as well as our hopes that this testimony may serve as well to him as to others engaged in honorable emulation to fructify these good

works, as an additional incitement to press the more vigorously on in every honest effort by this process to benefit the condition of mankind.

Professor Wolcott Gibbs then received the medals, and briefly returned thanks in Mr. Rutherford's name. He also added a few details of the methods and processes employed, and exhibited positives on glass of the sun and of a stellar cluster.

Professor A. Gray moved that the subject of the "New Survey" of the State be discussed; and the chair called upon Mr. S. H. Scudder to present the subject.

Mr. Scudder read a memorial to the General Court of Massachusetts, which he had prepared.

On motion of Professor J. P. Cooke, it was voted that the memorial be referred to a committee, to report at the next meeting.

The committee was constituted as follows: the President of the Academy, with Messrs. S. H. Scudder, T. S. Hunt, A. Agassiz, G. B. Emerson, W. B. Rogers, R. H. Dana, Jr.

Six hundred and sixty-eighth Meeting.

April 14, 1874.—MONTHLY MEETING.

The PRESIDENT in the chair.

The Corresponding Secretary read letters from L. C. Quetelet, of Brussels, announcing the death of his father, and from Charles Darwin, of Beckenham, and G. G. Stokes, of Cambridge, England, acknowledging their election as Foreign Honorary Members.

Dr. H. I. Bowditch read a notice of Dr. Louis, late Foreign Honorary Member of the Academy in Class II., Section 4.

The Corresponding Secretary presented by title a paper, by Dr. A. A. Hayes, "On a Practical Test of the Condition and Composition of Natural Waters."

Professor A. Gray communicated a paper, entitled "A Revision of the North American *Chenopodiaceæ*," by Sereno Watson.

Mr. W. A. Rogers presented a communication "On the Origin and Cause of Periodic Errors in the Observed Right Ascension of Stars."

Mr. S. H. Scudder read the memorial presented at the last meeting as corrected by the committee to whom it was referred.

It was voted to authorize the President to sign this memorial and present it to the General Court.

Dr. E. H. Clarke addressed the meeting on the action of the Mayor of Boston with regard to the establishment of a Public Park.

It was voted to appoint a committee to consider whether it was advisable for the Academy to take action in this matter, and if so to prepare a proper memorial.

Remarks on this subject were made by Messrs. E. H. Clarke, G. B. Emerson, A. P. Peabody, A. Agassiz, and W. Everett.

The President appointed Messrs. Clarke, Emerson, and Lowell to serve on this committee.

Six hundred and sixty-ninth Meeting.

May 12, 1874. — MONTHLY MEETING.

The PRESIDENT in the chair.

Professor Peirce presented a communication on Ocean Lanes for Steamships.

It was voted to appoint a committee for the purpose of inducing the adoption of such routes.

The following gentlemen were appointed members of this committee: Messrs. C. F. Adams, G. T. Bigelow, J. I. Bowditch, J. H. Clifford, and H. H. Hunnewell.

Professor E. C. Pickering presented a communication on a modification of the Graphical Method.

Mr. S. P. Sharples exhibited a piece of tin, showing marked corrosive action produced by water, and made a communication on this subject.

Mr. S. H. Scudder stated that the Memorial for a Gelogical Survey had been presented to the Legislature, and referred by them to the Board of Education.

The report of the Council upon the changes which have taken place in the members of the Academy during the past year was presented, and read in part by the Corresponding Secretary, as follows: —

The list of the Academy at present includes 194 Fellows, 85 Associate Fellows, and 66 Foreign Honorary Members.

Since the last Annual Meeting the Academy has received an accession of twelve new members. Three Fellows: viz., George L. Goodale, of Cambridge, in Class II.; George S. Hillard, of Boston, and Ebenezer Rockwood Hoar, of Concord, in Class III. Also nine Foreign Honorary Members: viz., C. F. Naumann, of Leipzig, in place of the late Adam Sedgwick; J. E. R. Clausius, of Bonn, in place of the late W. J. M. Rankine; James Joseph Sylvester, of Woolwich, in place of the late C. Delaunay; M. de Rémusat, of Paris, in place of the late Professor Trendelenburg; Friedrich Wöhler, of Göttingen, in place of the late Baron Liebig; George G. Stokes, of Cambridge, England, in place of the late Christopher Hansteen; W. E. Gladstone, of London, in place of the late J. Stuart Mill; Charles Darwin, of Beckenham, in place of the late Philippe E. D. de Verneuil; and Professor Brioschi, of Milan, in place of the late Monsieur Chasles.

During the year the Academy has lost by death sixteen members, as follows: five Fellows, viz., Louis Agassiz, of Cambridge, John L. Russell, of Salem, and John B. Perry, of Cambridge, in Class II.; Willard Phillips, of Cambridge, and Charles Sumner, of Boston, in Class III. Four Associate Fellows: viz., Henry James Clark, of Amherst, and John Bachman, of Charleston, S.C., in Class II.; Ira Perley, of Concord, N.H., and Hiram Powers, of Florence, in Class III. Seven Foreign Honorary Members: viz., Poncelet, Louis, Verneuil, Chasles, Kaulbach, Hansen, Quetelet, and De la Rive.

Louis Agassiz. — In the village of Motier, where his father was pastor, Agassiz was born, May 28, 1807. He was christened Jean Louis Rodolph. Motier is in the Swiss canton of Freyburg, on the northwest border of Lake Morat, and not far from the famed battle-field. It has been supposed that the Agassiz were Burgundian Huguenots driven from France by the persecutions under Louis XIV. As a fact, however, the family has been Swiss for three centuries or more. The ancestors of Louis had, for six generations, been of the same calling as his father; and those who like to trace the workings of atavism will, perhaps, regard his strong theistic turn of mind as an hereditary character. Not

so his passion for the study of nature, which grew with such intensity as to take complete possession of him by the time he had reached manhood. It was a growth not to be explained, and is an example of the multitude of exceptions to the so-called law of hereditary transmission. Already, while a boy, he began to collect insects at the gymnasium of Bienne; and, later, pursued a systematic study of the native plants of Orbe, a town on the great road over the Jura, whither his father had moved. At the academy of Lausanne he laid the foundations of a classical education, and in his eighteenth year began the study of medicine; for he was obliged to look forward to a time when his knowledge would be his only means of livelihood. After two years at Zurich, he went to Heidelberg in 1826, and there studied anatomy under the noted Tiedemann, and botany and zoölogy with Bischoff and Leuckhart. In the following year he entered the University of Munich, which then numbered very distinguished men among its professors. Oken, in some respects the most remarkable zoölogist that Germany has produced, there expounded his curious classification of the animal kingdom. Döllinger took the young Swiss into his house, and planted and fostered that interest in embryology which was to be a guide in his after career. His fellow-students remember vividly the remarkable appearance of Agassiz at that period, his active and powerful physique, the intellectual beauty of his face, his brilliant eye and gay laugh. Although a laborious and devoted scholar, he found time for athletic sports; and, as leading swordsman of the university, was elected president of the Swiss club, the *Helvetia*. At this the beginning of his scientific life, the bent of his mind towards a combination of natural history with metaphysics was already marked. While fitting himself for the practice of medicine, he attended Schelling's course of mental philosophy during four consecutive years; and this protracted study, in connection with the interest he took in the abstract theories of Oken, conclusively proves that the essential character of his intellect was the same in youth as in age. An irresistible passion, an intense longing to tear from Nature the secret of life, had now complete possession of Agassiz, and was destined not to lead, but to drive him during the remainder of his existence. The surroundings were, it is true, favorable, but it was because he sought them; and, had they not been favorable, he would have sought elsewhere. He has since said: "Our professors were themselves original investigators, daily contributing to the sum of human knowledge. They were not only our teachers, but our friends. The best spirit prevailed among professors and students. We were often companions of their walks,

often present at their discussions; and when we met for conversation or to give lectures among ourselves, as we constantly did, our professors were often among our listeners, cheering and stimulating us in all our efforts after independent search. My room was our meeting place, bed-room, study, museum, library, lecture-room, fencing-room, all in one. Students and professors used to call it the Little Academy." It was the opening genius of the young student of medicine that made his poor chamber a little academy. This also it was that impelled Martius to intrust to him, a youth of twenty-one, the description of the fishes collected in Brazil by Spix. They were published in a grand folio in 1829, with a sounding Latin title: *Selecta genera et species piscium quos collegit et pingendos curavit Dr. J. B. de Spix: digessit, descripsit, et observationibus illustravit Dr. L. Agassiz.* It will be seen that already he was a doctor of philosophy, having taken the degree in 1829; and he passed examinations for medicine and surgery, the following year. Such was the reputation acquired through his book, that he found facilities offered him on all sides. Cotta, the publisher, furnished funds with which to support an artist. Fitzinger gave him free access to the great collections of Vienna, whither he had repaired to study the Danube fishes; for ichthyology had, by the accident of Martius's patronage, become his leading study. Nor was it long before he pushed his inquiries from the living to the fossil, and there opened before him that vast field in which he was to gather so rich a harvest. In 1831 he lived in Paris, and there acquired the warm friendship of Cuvier. There, too, for the second time, he saw Humboldt, who became, and ever remained, his wise counsellor and generous friend.

With this episode ends the student life of Agassiz. He was about to begin a profession which was one day to become an engrossing one, and was never to be relinquished by him, — the profession of a teacher. In 1832 he applied to M. Louis Coulon to obtain for him a position as Professor of Natural History in the Gymnasium of Neuchatel. No such chair then existed; but M. Coulon raised enough money to guarantee for three years a salary of 2000 francs, and the new professor was duly installed, already considering the best way of laying out so considerable an annual sum as $400. He found no museum there, and for lack of a lecture-room was obliged to give his course in a hall of the town-house. But this ill-provided teacher soon brought his branch to overshadow all others in the gymnasium. He sent for the specimens he had amassed in Germany, and with ceaseless activity added fresh ones, until a tolerable collection was ready for display and study. Then, with the confidence of a man having abundant resources in money

and power, he proceeded to surround himself with the appliances of a great scientific centre, and to enter on a series of original investigations which might well have taxed the powers of half a dozen able men. He had constantly employed two artists, Weber and Dinkel, and a painter, Jacques Burkhardt, who had been his fellow-student at Munich, and who remained his life-long companion. Stahl, since noted as the best modeller at the Garden of Plants, was then employed at Neuchatel. Hercule Nicolet, summoned from Paris, was persuaded to set up, in this new home of science, a large lithographic establishment, where were published the last plates of the *Poissons fossiles;* those of the *Poissons d'Eau douce;* of the embryology of Coregonus; of the works on the Glaciers; and of the Echinoderms. That "Little Academy" of Munich now took on a new shape, and reappeared as La Société des Sciences Naturelles de Neuchatel. Its first meeting was in December, 1832, when Louis Coulon was chosen president, and Louis Agassiz secretary of the section of Natural History. It is needless to add that the section of Natural History was the important one in the society, and its secretary the important man of the section. The next fourteen years, during which he held the chair in Neuchatel, were especially his years of research and publication; and it is hardly conceivable that one man, even with able assistants, could within that period have done such an enormous amount of work. Thus far his attention had been directed chiefly to the class of fishes in which Martius had interested him. Their study had led him into paleontology, because of the great quantity of fossil species which had hitherto been the despair of ichthyologists. Fishes whose skeletons were soft, and which had thick muscles, were so crushed and distorted as to be unrecognizable, and the viscera were almost never to be distinguished. In the course of an exhaustive study of their anatomy, Agassiz discovered that the scales of fishes correspond by four kinds of structure to four grand natural divisions, which he called Ganoids, Placoids, Cycloids, and Ctenoids. With this basis, and aided by an intimate knowledge of the skeleton, he was enabled to tabulate all the known fossil species, to the number of a thousand; and these he published as *Recherches sur les Poissons fossiles,* in five volumes, with about four hundred plates of unusual excellence. This work, which was ten years in going through the press, was in itself enough to properly occupy a lifetime, and to give a reputation of the first class. In later years the author came to know that a classification founded on the scales alone was not without many exceptions, but it may well be doubted if any other classification has been discovered which comes so

near to the natural affinities. The preparation of these volumes was laborious in the extreme. Agassiz was obliged to travel with an artist, in order to examine and figure the specimens which could not be sent to Neuchatel. The expense, too, was far beyond his slender means, so that, despite the aid obtained through Humboldt and other warm friends, he incurred heavy debts, which hampered him for many years. He was, however, a man who counted neither money nor time nor labor when knowledge was in the balance, and he hesitated not to enter on new and intricate investigations in the midst of his original work. Such was the mental capacity of this naturalist, not yet thirty years old, and such his endurance of continuous labor, that these numerous threads of research, instead of producing a hopeless tangle in his mind, seemed each to serve as a separate clew to the truth of nature. Already he had turned a curious eye towards the vast ice masses which furrow the sides of his native mountains, and in 1834 made a report on the observations of Hugi concerning the structure of glaciers. His summer vacations spent among the high ranges gave him good chances to push an investigation whose importance grew each year greater in his eyes. It was in 1837 that he threw what can only be called a bombshell into the geological camp. In July of that year the members of the Helvetic Society of Natural Sciences had assembled at Neuchatel; and it fell to Agassiz, in his capacity of president, to deliver the opening discourse. It was the noted *Discours sur l'ancienne Extension des Glaciers*, in which he carried to its rigid conclusion the fact, already observed by Venetz and Charpentier, that boulders are transported and rocks scratched and polished by glacial ice; and inasmuch as Switzerland is strown with these boulders, and exhibits in many places the scratching and polishing of rock surfaces, he did not hesitate to cover the whole country with a sheet of ice of vast thickness, and to extend the same condition of things over the north of Europe. This awful heresy fell with startling effect on the ears of the assembly. Leopold von Buch, the greatest geologist of his time, lost all control of himself and denounced the new theory with unmeasured severity. When shown the scratched surfaces near Neuchatel, he replied that the slides of the school-boys had made them; and he retired at last, exclaiming, "O Sancte de Saussure, ora pro nobis." Nothing could better have promoted the progress of truth than such violent opposition. Agassiz was spurred to fresh exertions, and began next year a series of detailed explorations, which were continued for eight successive seasons, and were especially thorough in the neighborhood of Mont Blanc and in the Bernese Oberland. Determined to ascertain the

intimate structure and the movements of ice formations, he established himself, in the summer of 1840, on the median moraine of the Aar glacier, and lodged his party, which consisted of Desor, Vogt, Burkhardt, and Celestin Nicolet, under a large block of gneiss. This comfortless abode, which was invaded by frost at night and by trickling water in the daytime, was facetiously called *l'Hôtel des Neuchatelois.* Burkhardt used to relate how it was the privilege of him who first waked in the morning to direct with his finger the little streams of snow-water that meandered down the stone roof in such a way as to drip on the upturned faces of his sleeping companions. Such trivial anecdotes give us a vivid idea of the cheerful spirit in which these young men met the hardships and toil which were inseparable from their investigations. In 1842 a hut, of more comfortable character, was built on the bank which overhangs the left side of the glacier, and this served as a shelter during the rest of their visits. In 1840 and 1841 he published, in French and German, *Études sur les Glaciers,* accompanied by fine plates. His *Système Glaciaire,* with its maps and illustrations, did not appear till 1847. These great works, with numerous minor papers that accompanied them, have given Agassiz the deserved position of founder of the Glacial Theory.

While thus engrossed in geological and paleontological studies of the first importance, he still found time for other investigations. After a series of careful experiments in moulding, he produced in 1839 his paper *Sur les Moules de Mollusques vivans et fossiles.* Therein he showed that the soft parts of mollusca impress their form on the interior of the shell, which form can be reproduced by a cast, whose inequalities will represent those of the original animal. Therefore the *casts* of mollusks, so numerous in certain formations, were no longer to be considered as worthless. Passing from known to unknown, he first made interior casts of living shells, and studied them side by side with the animals; and the knowledge of the organs thus obtained was applied, *mutatis mutandis,* to fossil casts. This essay was followed (1842–45) by his *Études critiques sur les Mollusques fossiles.* During the same period his attention was further drawn to two lines of research which were destined to interest him ever after. They were the Radiata and the study of Embryology. The latter was confined to the development in the egg of the Swiss white fish (*Coregonus palaea*). Experiments continued through several seasons on artificially fecundated eggs were conducted, under the direction of Agassiz, by Karl Vogt, and were published in 1842 as a part of the *Poissons d'Eau douce.* And it is worthy of note that the government of Neuchatel issued in

that year directions to fishermen for the impregnation of fish eggs, — an event which antedates the rediscovery of pisciculture by Rémy.

Agassiz did not, at that time, pursue further these observations; but it is plain that he pondered them much, and that they recalled the teachings of his good master, Döllinger, on the relations of embryology to zoölogy. His reflection was to take form some years later, and to throw new light on the intricate question of animal succession.

Echinoderms attracted the attention of Agassiz almost as early as fishes. His paper *Über die Echinodermen* appeared in the "Isis" in 1834, and in 1839 he published an admirable anatomical essay on Astrophyton. Doubtless the peculiar plan of structure of this class, so simple in theory and so varied in practice, struck him as one which might be intelligible, and might give solid points from which to approach the more complex plans. To these considerations was added the advantage of a wide distribution both of the living and the fossil representatives. However it may be, he pushed the investigations of Echinodermata with extraordinary energy and thoroughness, and was aided in the task by Desor. From 1838 to 1842 there appeared his *Monographies d'Echinodermes vivans et fossiles*, including a remarkable anatomy of the common sea-urchin, by Valentin. The preparation of this standard work was connected with some of Agassiz's happiest days, when he used to visit Paris for the sake of the great collections at the Garden of Plants, and for intercourse with the eminent men of science who were gathered there. And now, at the age of thirty-five, he had already put forth books on fishes, mollusks, and echinoderms, and on the geology of the drift period, any one of which would have given a reputation. During his fifteen years of arduous study, he had, with a care for detail scarcely to be expected in so ardent a character, prepared long lists of the generic names which occurred in his reading; and he conceived the idea of extending these lists so as to include the known genera of the entire animal kingdom. The work was revised and enlarged by twenty-two colleagues, each of whom took a group; and the whole was completed in 1846, under the name of *Nomenclator Zoölogicus.* It was as if the author had come to a period in his labors, and had made an index; for there was presently to be a change in his life and in his home.

At the suggestion of Lyell, Mr. John A. Lowell had, in 1845, invited Professor Agassiz to come to Boston and deliver lectures before the Lowell Institute. About the same time the King of Prussia, through the ever-thoughtful mediation of Humboldt, had presented him with a sum of money in aid of a scientific mission to America. Thus encouraged by invitation and by pecuniary aid, he crossed the

Atlantic in the autumn of 1846, and made his *début* in the United States as a lecturer. A new country brought a new life and a different direction of energy. Hitherto Agassiz had been the brilliant discoverer, now he was to be the explorer and the teacher. It is true that the monographs he published during his American residence were numerous, and worthy of his former fame; yet they were not his distinguishing glory, as similar works had been in Neuchatel. So far as natural science was concerned, he found a people untaught and a country unexplored. He lectured, and was delighted at the interest he created, and the spirit of research that was roused. He fell to collecting, and gathered specimens with all the glee of a boy who has a holiday in a fruit garden; for Agassiz had to the full the boyish spirits that often characterize men of enthusiasm. In 1847 Mr. Abbott Lawrence, with the same judicious selection that M. Coulon had shown fifteen years before, offered to found for Agassiz a professorship of zoölogy and geology in the Scientific School at Harvard College. It was then that he obtained an honorable discharge from his European engagements, and fixed his abode in this country, where he could enjoy a social power and a freedom such as are seldom accorded to scientific men in the Old World. In 1848 he explored Lake Superior, and an account of the observations there made was edited by Mr. J. Elliot Cabot. At the request of Professor Bache of the Coast Survey, he passed the winter of 1850 among the Florida reefs, where he determined the law of growth by which that peninsula has gradually extended southward by the successive formation of reefs, keys, and mud flats. His stay at Charleston, S.C., led to his appointment, in 1852, to the chair of Comparative Anatomy at the Medical College, which he held for two terms, when a dangerous fever, brought on by exposure in collecting, compelled him to give up the position. He published in 1853 a paper on the newly discovered viviparous fishes of California, and he began also to turn his thoughts towards the elaboration of the vast material he had collected in America. Perhaps he remembered the little gymnasium in Switzerland and the great books that there grew up, and feared his colleagues might grow impatient at his long silence. The series of essays which he sketched was to be called "Contributions to the Natural History of the United States," which he hoped to carry to ten volumes. Nothing better showed the popularity of Agassiz than the subscription to this work, which reached 2,500 names. Of the series, only four volumes were published, while a fifth was left unfinished. They are: An Essay on Classification; North American Testudinata; the Embryology of Turtles; and the Acalephs, under

which were included monographs of the Ctenophoræ, Discophoræ, and Hydroidæ, and an essay on the homologies of the Radiata. His chief assistant in their preparation was the late Professor H. J. Clark. They were illustrated by lithographic plates, which have never been surpassed in excellence, and the best of which were drawn by Sonrel.

The "Essay on Classification" is the flower of the mature thought of Agassiz. In it may be discovered the elaboration of ideas which are scattered through his earlier productions. To properly appreciate this masterly disquisition, it must be remembered that Agassiz had always a metaphysical mind, and one in which the idea of intelligent power was a ground principle. Although he had not accepted the results of Oken, he heartily admired his spirit, and ever spoke of him with pleasure.* Indeed, he may be said to have adopted the method of Cuvier and the inspiration of Oken. Advancing from this point, Agassiz interprets the phenomena of Not-self by those of Self. The last paper that came from his hand, "Evolution and Permanence of Type," has this sentence: "*It cannot be too soon understood that Science is one; and that, whether we investigate language, philosophy, theology, history, or physics, we are dealing with the same problem, culminating in the knowledge of ourselves.*" The human mind is for him an entity in accord with the Creating Spirit, and capable therefore of studying and appreciating creation. This study and this appreciation he considers Science; and he finds in the animal kingdom the physical expression of various intellectual operations, some sharply defined and some shadowy, some simple and some hopelessly complex, just as are the familiar workings of the human mind. Not only is his erudition throughout remarkable, but his grasp of facts, intricate in their relations and numerous, is quite amazing. In nothing is this better exhibited than in his celebrated demonstration of the correspondence of embryological, geological, and zoölogical succession. He shows that, in many orders, the species which first appear in the older beds resemble the embryo of the highest species now living; and, moreover, that this fossil and this embryo have characters in common with the living species that stand lower in the zoölogical scale. Thus among Crustacea the living Brachyurans stand highest; but the embryo of the Brachyuran has a long tail like the Macrourans, which are characteristic of the middle geological periods, and among the living are zoölogically inferior to the Brachyurans.

* Essay on Classification, p. 336.

Agassiz was, however, not destined to resume his old habits of investigation and publication. The will of Mr. Francis C. Gray established in 1858 a fund for the support of a Museum of Comparative Zoölogy; and a liberal private subscription, seconded by a large gift from the State, assured the future of the establishment. Henceforth the current of Agassiz's thought ran in a new channel. In the words of a recent notice of him: "He determined to found a great museum arranged to show his views of the relations of living animals among themselves, and their connections in the geological and embryological successions. Such a museum he hoped to leave as a legacy — his all — to the people of this country, and to make it at once a mark of his affection and a monument of his labor. He gave less and less of his time to those special investigations by which he had gained his reputation, and pondered more and more on this museum which should serve as a sort of tabulation of the creative thought by presenting the creations themselves in a connected order."

Day by day he labored to increase the collections, and to push their arrangement. His Brazilian expedition, undertaken in 1865, at the cost of Mr. Nathaniel Thayer, brought back vast riches; but not even the sight of familiar fishes, that took him back to Munich and the time of Spix and Martius, could turn him again to special studies. He kept on with ever-increasing toil, and yet preserved his relations to the public, his popular lectures, his interest in education and agriculture, his voluminous correspondence. All this, in addition to his duties as Professor of Natural History, was too much even for his powerful frame, and in 1869 he was seized with a cerebral attack which threatened his life. From it he recovered only to enter, with all the spirit of a youth just beginning the world, upon the Hassler expedition of 1871, which was under the direction of the Coast Survey. He endured without complaint the hardships of a voyage round Cape Horn in a small steamer, and returned laden with new collections.

The last year of his life was a very happy one. He saw the museum well supplied with funds, growing in size, and advancing towards arrangement. There came besides, from Mr. John Anderson, the gift of the Island of Penikese and of a large sum in money, to found a summer school of Natural History. It was at once started with about fifty pupils, and Agassiz had the great pleasure of founding the first establishment of the kind in the world.* But he killed himself in

* The station of Dr. Dohrn, at Naples, is of a different character, and was not then in working order.

doing it. It was precisely this new and prolonged strain, at a season when usually he took a sort of vacation, that shattered his system beyond the power of repair; and on December 14, 1873, he died.

If we consider simply the influence of his philosophical opinions on the mass of scientific men, Agassiz lived too late and also too early. At all stages of its progress, the human mind presents a kind of atrophy of some of its parts; and he who treats of such topics as are appreciated only by these parts speaks to deaf ears. Continuance in one set of opinions through several generations produces at last lassitude, then a sort of rebellion, and finally the welcoming of any thing novel, as a glad relief. Here is a great, if not the greatest, cause of changes, which are, on the whole, beneficial. The tree of knowledge at such times throws out new and strong branches, albeit they are all on one side. Thus it has been with natural science. Scholars got tired of Bridgewater treatises, and talk of means and ends, and of plans of creation; moreover, they were in some places exasperated by opposition from Church or State. Then they were getting suffocated by their material; and, when the species of shells increased to thousands, and of beetles to tens of thousands, they exclaimed, "It is enough, — give us relief!" Their relief was like that of the Mediæval Catholic Church. Positivism advanced, and said: "Bury every thing that is inconvenient, and come and lean on me, and I will give you peace. Thought and causation have no real existence. They and you are only figures in a procession that has neither beginning nor end. Amuse yourselves, therefore, by looking at this procession, until the inevitable comes upon you." This is the philosophy which to-day is powerful among thinking men; and its tide is fated to rise higher before it ebbs. Like all systems, it will work good and evil; but its good will remain, and its evil melt away.

Against such a current Agassiz struggled in vain. He was a theistic philosopher, who chose for his field the working of Supreme Thought in the animal creation. He addressed a world of learned men, the majority of whom could not understand what basis theistic philosophy had, and of whom not a few accused him of want of honesty for even introducing such a theme. The time will come when his power and insight will be appreciated. Meanwhile we must be content with his successes that lay in a lower plane: they were his special zoölogical investigations, and his brilliant career in the United States, where he roused an enthusiasm for high studies, and where he established a great centre of science.

JOHN LEWIS RUSSELL, who died at Salem on the 7th of June last, was the son of Colonel John and Eunice (Hunt) Russell, and was born at Salem, December 2, 1808. He entered Harvard University in the year 1824, was graduated in 1828, and took the master's degree in 1836. He studied for the ministry, was in due course licensed to preach, and was settled over Congregational Churches in Chelmsford, Brattleborough, and Hingham. But for the last twenty years of his life he resided in his native town, withdrawing from ministerial labors and directing his attention chiefly to scientific investigation. He was an acute naturalist, mainly a botanist, and by predilection devoted to the Cryptogamia. He was probably, like his former associate, the late William Oakes, of Ipswich, a pupil of Dr. Osgood of Danvers, or at least drew his inspiration for botany from him, as he in turn did from the Rev. Dr. Culter, of Essex, — the pioneer of the science in Essex County (where his influence has not yet died out, nor indeed in all New England). Mr. Russell was one of the founders of the Essex Natural History Society, which in 1848 became a department of the Essex Institute, of which he continued to be an active member and officer. He served the Boston Horticultural Society for a long series of years as its Professor of Botany and Vegetable Physiology, *i. e.* as its scientific adviser; and by his lectures in lyceums and schools he did a good deal for education in this department. For many years he probably knew more of the cryptogamic botany of this part of the country than any one else. He is said to have been the first in this country to use the microscope in the systematic study of lichens. But his means, his correspondence, and his range were limited, so that he did not push his way far; and, as he has published very little indeed, it is to be feared that his name will not be so long or so widely remembered in the annals of the science as it ought.

His genuine and disinterested devotion to the science of his predilection, manifested in all his life, was shown in the disposition he made of his small property. This he bequeathed (subject to the life-interest of two near relatives), one-third to the Massachusetts Horticultural Society, to promote investigation in respect to the connection of the Fungi with horticulture; the remainder to the Botanic Garden and Herbarium of Harvard University. His collections he bestowed upon two newly formed local Natural History Societies of his native State, one at Natick, the other at Springfield.

JOHN BULKLEY PERRY was born in Richmond, Berkshire County, Mass., December 12, 1825. His early youth was spent in Bur-

lington, Vt., a region which was admirably fitted to plant in him the love of geology. Here he entered the University of Vermont in 1843, whence he was graduated in 1847. Being of a frail constitution, the work of an arduous collegiate career left him with impaired health, and led him to seek a warmer climate. This he gained by a residence of some three years in the Southern States. Although employed as a teacher for most of this time, he yet found the leisure to make considerable studies of the rocks of the regions he visited. Returning to the North in 1850, he entered the Andover Theological Seminary. After receiving "approbation to preach," and supplying the pulpit in several places, he finally settled at Swanton, Vt., where he remained in charge of the pastorate for eleven years. During the Secession War he was for a time a delegate of the Christian Commission, and later the chaplain of the 20th Vermont Regiment. In both of these posts he did the faithful and loving service for which his nature so well fitted him. In these little famous but most important duties he saw some of the greatest events of that war, the storming of Petersburg and the surrender of Lee among them.

It was this residence at Swanton that did the most to decide his future career. There he found himself in face of some of the most difficult problems of American geology; and, with the patience and bravery which was characteristic of the man, he did not hesitate to undertake their solution. Several contributions concerning these rocks and a large amount of unpublished matter mark this period of his life. So little disposed was he to claim attention that, had it not been for an accidental contact with Professor Jules Marcou, who recognized his merit and urged him to take his proper place among American geologists, he would probably have passed his life satisfied with the personal satisfaction that knowledge gives.

In 1867 he came to Boston, and was given a position as assistant in the Museum of Comparative Zoölogy, under Professor Agassiz. His considerable studies in the Southern tertiaries especially fitted him to arrange the large amount of material in that part of the paleontological collection. This work he in good part accomplished, and it will long remain a monument of his accuracy and devotion. In 1870 he made for the museum an extended collecting tour through the Southern States. This work, protracted into the summer long after his health gave signs of failing, and urged forward with a zeal which great love for the work inspired, planted the seeds of serious disease. In 1871 he became the occupant of a chair at Oberlin College in Ohio, with the idea of giving half of the year to his work there and half to his old

work at Cambridge. He entered on his duties with enthusiasm, but the willing soul found scant support from the enfeebled body. After his first course of lectures, he strove to find new health in a journey with his students in Iowa; but this resource failed him, and he returned to Cambridge with mortal illness upon him, and died on the morning of October 3, 1872.

Professor Perry well represented a class of workers, unfortunately few in this country, who combine the duties of pastoral teaching with the prosecution of scientific researches. Had his life been prolonged, he would undoubtedly have achieved a first place among those who have sought to reconcile the teachings of Christianity with the record of the great stone book. In his few published papers, this effort to reconcile our newly acquired knowledge with the doctrines which form the essential basis of our civilization plays a large part. Here, as well as in his more purely scientific writings, his great modesty, leading him generally to anonymous publications, makes it well-nigh impossible for the writer of this memoir to prepare a catalogue of his papers. His geological publications were mainly limited to the rocks of New England; but in his lectures, which were not prepared for publication, he propounded certain general views of originality and importance. Most deserving of memory among these was his theory of the origin of the mica schists and other foliated rocks. These he considered to have been formed by the precipitation of their components from the atmosphere, immediately after the cooling of the primeval crust to the point of solidification. While the writer is not prepared to accept this view, he must bear testimony to the ability with which Professor Perry advocated it.

The following papers were published by Professor Perry in the Proceedings of the Boston Society of Natural History: —

Vol. XI., p. 341. December 18, 1867. Queries on the Red Sandstone of Vermont, and its Relations.

Vol. XII., p. 214. December 2, 1868. Sketch of the life of Dr. Ebenezer Emmons. Same, page 219. December 2, 1868. Remarks on Indian Relics seen at Swanton, Vt.

Vol. XIV., p. 68. December 21, 1870. Remarks on the Glacial Theory. Same, page 199. April 19, 1871. Remarks on Eozoon.

Vol. XV., p. 48. February 28, 1872. Hints towards the Post-tertiary History of New England, with remarks on Dana's "Geology of the New Haven Region."

Willard Phillips was born on the 19th of December, 1784, at Bridgewater, Mass. His childhood and youth were passed in various towns in Hampshire County. After such training as the common country schools could give, at the age of eighteen he commenced teaching such a school. His second engagement as a teacher was in Chesterfield, where began his acquaintance with William Cullen Bryant (ten years his junior), which ripened into an intimate and life-long friendship. Here he received his earliest lessons in Latin; and he continued alternately teaching and studying, until he was prepared to enter Harvard College in 1806. He graduated with high honors, and was shortly afterward appointed to a tutorship, which he held for four years. He was during this period a frequent contributor to the current periodical literature, and was among the earliest writers for the "North American Review," of which he was for a short time proprietor and editor.

On leaving Cambridge, Mr. Phillips entered upon the practice of the law in Boston. In 1825 and 1826 he was a member of the legislature. In 1837 he was chairman of a commission, appointed by Governor Everett, for codifying so much of the common law as falls within the range of criminal jurisprudence. In 1839 he was appointed by Governor Everett Judge of Probate for Suffolk County, which office he resigned in 1847, to become President of the New England Life Insurance Company, continuing to serve in that capacity till the growing infirmities of age made it expedient for him to resign all active duty.

Judge Phillips was an able and learned lawyer, and while at the bar was distinguished for prompt and keen insight into the legal bearings and merits of the cases in which he was concerned. In 1823 he published the first edition of his treatise on Insurance, which has passed through many successive editions, greatly enlarged, and kept on a level with the new legal learning of the day. This book has, from its first appearance, been regarded as a standard work in England as well as in the United States. Judge Phillips's son on a recent occasion received in London distinguished attention from prominent members of the Bench and Bar, in recognition of his father's just claims to respect and honor. In 1829 Judge Phillips published "A Manual of Political Economy," which manifested no little research, erudition, and acumen, but was vitiated for permanent and general reception by its partisan advocacy of the system of high protective duties. In 1850 he published, in the same vein of thought, a volume entitled "Propositions concerning Protection and Free Trade." In addition to these more important labors, he edited several legal works

with annotations, and wrote the article on Political Economy in the Encyclopædia Americana.

The latter years of Judge Phillips's life were passed at his home in Cambridge in the enjoyment of books, — so long as he could employ his eyes and mind upon them, — of attached and devoted kindred and friends, and of the tranquillity that is wont to attend the close of an active and honorable career. Gentle, kind, serene, happy, he sank by slow decline, with no symptoms of acute disease, and died on the 9th of September, 1873; leaving the record of a pure and upright life, and a name held no less in loving memory than in enduring reverence and honor.

Charles Sumner was born in Boston, 6 January, 1811. He received his education at the Latin School of that city and at Harvard College, where he took his first degree in 1830. Animated by a great ardor for knowledge and indefatigable industry in acquisition, he entered at once upon the study of the law, under the auspices of the eminent judge, Joseph Story, who was just then laying the solid foundation for that department of education connected with the University, which has maintained its reputation ever since. That distinguished man was not slow to detect the brilliant qualities of the new scholar, and under his guidance Mr. Sumner enjoyed a privilege of entering upon the practice of the profession which is not given to many young men. That he did not prosecute his work was doubtless owing to the fact that he soon discovered himself to be better fitted for another sphere of action. A visit to Great Britain and France, where under the warm recommendations of his master he was enabled to see much of the most refined society of these countries, probably contributed to turn his mind in a different direction. However this may be, the fact is indisputable that, after his return, his professional ardor became relaxed, and before long was extinguished altogether.

Neither could this change have caused surprise to any one well acquainted with the character of the man. His mind possessed unquestionable power; but it was not of that kind which patiently exerts itself in the acute definition of logical distinctions, or in the colder measurement of balancing probabilities of truth. He had nothing of the temperament which reduces every effort of reason or evidence of fact to precisely its just value, and no more, — a temperament most necessary to high reputation as a lawyer or a judge. Mr. Sumner could not have gone very far in this path without discovering that this was not the sphere in which he could best develop his most brilliant accomplishments. An incident soon occurred which determined the question

for him almost without a struggle. On the 4th of July, 1845, at the request of the authorities of the city of Boston, he delivered the oration customarily given upon that anniversary. The topic which he selected was the preservation of peace as the true policy of all nations, — a tolerably well-beaten subject, but handled on this occasion with so much power of illustration and such vigorous oratory that it produced an effect upon the auditory far exceeding that of any similar production of late years. Then it was that Mr. Sumner probably discovered the true nature of his vocation. From that moment his career was marked out for him.

This production, to which he affixed the title of "The True Grandeur of Nations," gave the key-note to all the later efforts of his life. It disclosed an impetuosity of enthusiasm well adapted to awaken sympathy in the popular heart, and it cast a glow over reasoning and imagery which dazzled, if it did not altogether convince more scrutinizing minds. A reader who would now set himself to a calm analysis of the argument, by the light of the experience of the world, especially including that of the United States in the course of the thirty years since elapsed, could not fail to note its chief defect, — an extreme of speculative optimism, and a corresponding failure in the adaptation of unquestioned general principles to the easy attainment of really useful ends.

The brilliant success of this first effort in favor of universal peace happened just at a moment when another agitation was in process of inception, equally founded upon a great principle of morals, and far more susceptible of application to the existing condition of things, whilst it called for precisely the same kind of ability indicated on that occasion. The country had been shaken to its centre nearly thirty years before by the first conflict of power springing from the rapid spread of the slave element over a vast space of its territory, — a conflict which was then only postponed by a compromise suddenly patched up between the two parties in Congress that time. Although the pacification appeared for a while to have been founded upon almost universal popular consent and a fixed determination to countenance no effort to revive the topic, and though the entire movement of the government of the country was regulated in that sense, yet so dangerous to all sound doctrines of freedom was the progress of the power visibly concentrating by the rapid development of this adverse element on which it rested, that it could not fail sooner or later to rouse attention and create alarm among close observers of the phenomena as they presented themselves. The violent measures at first

resorted to for the purpose of suppressing by force all public demonstrations of dissatisfaction only had the natural effect of spreading the uneasiness; and this uneasiness soon took the form customary in a free country, of the combination of numbers to promote by their union the common object of resistance to that which in the established state of things they disapproved.

Such in brief was the rise of the anti-slavery party in American history. It was just beginning to change its character of a purely moral protest to an effective political resistance, at the moment when Mr. Sumner had fully discovered his aptitude for speaking before the people on precisely this order of public questions. He at once entered into the movement with the ardor natural to his disposition. No wider field for the development of his peculiar gift could have been presented, and he availed himself of his opportunities most effectively. From this date he altogether abandoned his professional career, and embarked, in stormy conflict, on the voyage of anti-slavery politics.

Neither was it a great while before the growth of the party with which he had associated himself had become sufficient in Massachusetts, if not to control its action, at least to hold a balance between the two older and antagonist organizations which had previously ruled. The consequence was a combination, not altogether defensible on purely moral grounds, though rarely declined in practice, by which, at the expense of surrendering the control of the State government for the year into the hands of the party least in sympathy with its own great object, it secured the extraordinary advantage of placing through their aid Mr. Sumner as their champion in the Senate of the United States.

The field being now open before him, Mr. Sumner lost no time to profit by the opportunities for advancing his cause. The result was the production of a variety of speeches, all of them in a bold and trenchant style of oratory, well calculated to impress itself strongly upon the minds of multitudes. The severity of his invective in one instance roused the passions of a youthful member of the House of Representatives to such an extent as to prompt a personal assault upon him, which practically disabled him for three years. But the moral effect of the blows was only the more surely to perpetuate his retention of his elevated position, and vastly to increase his influence over the community. He continued by successive elections to be a member of the Senate for a period of three and twenty years, until his death, which took place at Washington on the 11th of March, 1874.

A collection of his works in ten volumes, prepared under his own supervision, has been made, and is still in process of publication. Although largely composed of vehement political controversy, the interest of which passes away with the progress of time, and the cessation of the causes that gave rise to it, they will always bear witness to the nobler qualities of the man, to the power of his eloquence, to his indefatigable industry, and to the extent of his literary and moral as well as his oratorical attainments.

HENRY JAMES CLARK was born at Easton, Mass., June 22, 1826, and died July 1, 1873. He received a collegiate education at the University of New York, graduating in the year 1848. From thence he went as a teacher to White Plains, N.Y.; and while engaged in his favorite study, botany, made observations upon the structure of Mimulus, which he communicated to Professor Gray. This and subsequent observations upon the flora of the neighborhood attracted to him the favorable notice of the latter. Becoming dissatisfied with teaching, and obtaining the necessary encouragement and assistance from Professor Gray, Mr. Clark came to Cambridge. Here he enjoyed for some time the advantages of a pupil and private assistant at the Botanical Garden. Later, however, a taste for zoölogical studies, developed by the lectures of Professor Agassiz and frequent visits to the zoölogical laboratory, led him, in the fall of 1850, to abandon botany for what appeared to him the more fascinating study of animal life. Graduating from the Lawrence Scientific School as Bachelor of Science in 1854, he became immediately after the private assistant of Professor Agassiz, who ever accorded him the highest character as an observer and faithful student.

The writer's personal acquaintance with Mr. Clark began in the fall of 1858. He was then engaged, as assistant to Professor Agassiz, in working out of many of the most important anatomical details of the great work entitled "Contributions to the Natural History of North America," of which two volumes had already been published. The plates bearing his name in the second and subsequent volumes of these contributions attest the great fidelity and thoroughness of the works which he has done, and the masterly command of the microscope which distinguished his subsequent labors. In conjunction with Professor Agassiz, he exercised an influence in developing the genius of Spencer, the eminent microscope-maker, and of his pupil, Mr. R. B. Tolles; and his success with their objectives largely added to the reputation of these skilful opticians.

Mr. Clark was appointed Adjunct Professor of Zoölogy at Harvard College in the year 1860, which post he subsequently resigned in consequence of a disagreement which arose between himself and Professor Agassiz with reference to the work he had been doing under his direction. His own views of this unfortunate controversy have been published in a pamphlet entitled "A Claim for Scientific Property." During his residence at Cambridge, various communications from him were read before this Academy, and the Boston Society of Natural History, upon the microscopical structure of plants and of the lower animals. He was particularly engaged at this time in researches upon the structure and physiology of Lucernaria. The earlier results of the investigation were given to the Boston Society of Natural History, in March, 1862, in a paper entitled "Lucernaria the Cœnotype of the Acalephæ;" but the Prodromus published in January, 1863, contained only a brief statement of the work, and the materials afterward swelled to such dimensions that it became impossible for the Society to publish it. The Smithsonian Institution finally undertook the task; and the monograph, not yet published, will fill about four hundred pages quarto, and will be illustrated by forty plates.*

In January, 1864, Professor Clark announced the discovery of the eggs of Tubularia. This group had previously puzzled observers, by presenting the anomaly of a female form producing young by a system of budding and destitute of true ova, though the male elaborated spermatozoa. This discovery led Professor Clark to the very important conclusion that "there was but one type of development in the Medusoids of all the Hydroids," — an exceedingly valuable addition to our knowledge of the affinities of the various groups of Medusæ. During the course of these observations, he was attracted to the study of still lower forms; and we find him in September, 1863, publishing an important contribution, in which he demonstrated the cellular structure of Actinophrys, Difflugia, and other forms, and finally in December, 1865, comparing the structure of the Cilio-flagellati Infusoria with that of true sponges, and announcing his opinion that Leucosolenia, a form of calcareous sponge common on this coast, was really a compound mass of monads, allied to Codosiga. In this conclusion he has been supported by the observations of Carter, and opposed in common with Carter by Hæckel in his late work upon calcareous sponges.

* See Prod. of the Hist., Struct., and Physiol. of the order of Lucernaria. Boston Jour. Nat. Hist., vol. vii. p. 531.

Notwithstanding his constant investigations, Professor Clark found time to prepare a course of lectures of a thoroughly philosophical and general nature, which were delivered before the Lowell Institute in the winter of 1864. These were subsequently rewritten, and appeared in the form of a book, under the title of "Mind in Nature," in 1865.

It is evidently the work of a student capable of handling the entire animal kingdom; and the three hundred and fifteen octavo pages are crowded with original observations, clearly and distinctly stated in a popular and readable form, and illustrated by four hundred and twenty drawings, one hundred and forty of which are original.

Professor Clark was appointed to the chair of Zoölogy in Pennsylvania Agricultural College in the year 1866, where he remained only three years, exchanging it for similar duties in the University of Kentucky, at Lexington, in 1869.

Neither of these situations was agreeable to his tastes, owing mainly to the pressure of collegiate duties, which prevented him from following out abstruse investigations. He therefore accepted with great readiness the offer made him, in 1872, of the chair of Veterinary Science in the Agricultural College of Massachusetts. Here his duties were of a more congenial nature; and he had applied himself with renewed energy to the formation of a museum of comparative anatomy, when his labors were interrupted by his final sickness.

The personal qualities of Professor Clark were of a kind to endear him to many friends, especially to those students who sought and obtained from him counsel and advice in their studies, as the writer did on many occasions. His uniform courtesy of manner, though often in ill-health; his unswerving devotion to scientific pursuits, though for years laboring under pecuniary difficulties, — are worthy of the highest praise a biographer can bestow.

He has earned by his labors a right to be classed as one of the closest and ablest of the zoölogical observers, and as the finest and most experienced microscopist which this country has yet produced.

John Bachman was born February 4, 1790, in Rhinebeck, Dutchess County, N.Y. He was descended from an old German family, who originally came to this country at the time of William Penn. At the age of twenty-three he was licensed as preacher by the Lutheran synod of New York, and was settled in Rensselaer County of that State. Owing to ill-health, he was compelled to seek employment at the South; and he reluctantly resigned his first charge. The Lutheran Church of

Charleston selecting him as their pastor, he proceeded to his new home in 1815. During twenty-three years he devoted himself to his pastoral duties, and was active in organizing and establishing evangelical Lutheran churches throughout the South. In 1838 ill-health compelled him to go to Europe; but he returned, after a short absence, to Charleston, and worked uninterruptedly in the enjoyment of excellent health till a few years before his death, when he became prostrated by paralysis, and only preached rarely. He died February 15, 1874.

He was one of the pioneers of science in this country, and, though he paid considerable attention to geology and botany, he devoted himself more particularly to zoölogy. He published with Audubon the Quadrupeds of North America, his principal zoölogical work. He paid considerable attention to ornithology, and Audubon has repeatedly acknowledged his obligations to him for valuable information. Dr. Bachman was a constant writer in the various periodicals and journals of the South. He took a very active part in the discussion of the question of the unity or plurality of origin of the human race. His principal contributions to the subject are his "Unity of the Human Race;" an examination of the chararacteristics of genera and species as applied to the doctrine of the Unity of the Human Race; and a review of Nott and Gliddon's "Types of Mankind." Dr. Bachman always took the strictly orthodox view of the subject, and frequently allowed his religious opinions, which were very decided, to warp his criticisms of his scientific adversaries. He possessed an eminently German industry, he was exceedingly thorough in his work, wrote with great facility, and attained eminence in science at a time when original investigators in this country were few indeed. With him passes away the last of the prominent members of the scientific circle for which Charleston was celebrated during the life of Dr. Holbrook, in the flourishing days of its Medical School.

Ira Perley was born in Boxford, Mass., November 9, 1799. He graduated at Dartmouth College in 1822, studied law with Hon. Daniel M. Christie, of Dover, N.H. (who survives his pupil), entered on the practice of his profession at Hanover, N.H., whence he removed to Concord, and continued a resident of that city till his death, February 26, 1874. His high professional reputation may be inferred from the fact that he was appointed to the bench of the Supreme Court by a governor of the political party opposite to his own, in a State where appointments from other than the dominant party have been among the rarest

of events. This was in 1850. He was made Chief Justice in 1855, and resigned in 1859. He was reappointed Chief Justice in 1864, and retained the office till 1869, when, in full vigor of mind and with unabated capacity for labor, he returned to the practice of the law, and held the foremost place at the New Hampshire bar, till the summer preceding his death.

Judge Perley was regarded by his brother lawyers as without a superior, and with few equals, in legal learning and ability; and as a judge he holds a worthy place among the eminent jurists who have for half a century or more given to the decisions of the New Hampshire bench an authority and influence recognized in all our courts. He was at the same time a life-long student of classical literature, and more intimately conversant with its best authors than many who have professedly devoted themselves to this branch of learning. In his social intercourse, without pretension or display, he gave always the impression of a mind natively strong and versatile, and enriched by the most liberal culture. In all relations, domestic, social, and civic, he has left the record of conscientious fidelity, purity, and integrity, — a name honored and beloved in his life, and held in reverent memory, most of all by those who knew him best.

Hiram Powers. — When a remarkable man passes away, we naturally endeavor to fill the void he leaves with remembrances of his achievements; and all incidents which bear upon his career, or relate to his development, possess peculiar interest.

The facts presented in the following memoir were gathered from notes taken in Florence, from Powers's own lips, in 1842, by George H. Calvert; and we esteem ourselves fortunate that, through the kindness of that gentleman, we are able to supply such trustworthy information. These notes refer to Powers's early life, up to the date of his arrival in Florence, since which time his career is better known.

Hiram Powers was born at Woodstock, Vt., July 29, 1805, the son of a farmer who lived near the village. His paternal grandfather's grandmother was an Indian. Hiram went to school in Woodstock until he was fourteen years of age. The only schooling he had after this was a few lessons in Latin, two years later, given him by an elder brother, a graduate of Dartmouth College. While in school at Woodstock, his talent for drawing and for mechanics first showed themselves.

In his fourteenth year his father emigrated to Ohio, where, for the first year after his arrival, Hiram lived and worked on a farm near

Cincinnati. About this time he lost his father, whereupon he went into Cincinnati to seek his fortune.

His first occupation was as keeper of a small reading-room attached to the Broadway and Front Street Hotel. His talent for mechanics now exhibited itself very actively. Much of his leisure he spent in steam-engine factories. His thoughts were busy with the application of steam to carriages on rails. He contrived a small machine to test the practicability of flying. While at the reading-room, and when he was about the age of seventeen, he first saw a piece of sculpture. This was a cast of Houdon's head of Washington. The mechanical execution of the cast was what first acted on his mind, and he was puzzled to understand how it was made. Then he was struck with the grandeur of the head; and, as he gazed at it, he thought how unattainable was the art of bringing out such a head from a block of marble.

At the end of a year he left the reading-room for a place in a "Produce Store." . . . About this period he had opportunity of seeing engravings from some of the antique statues. The close of another year found him in a new situation, that of assistant to the county tax-gatherer, his duty being to ride through the country on horseback, in winter, collecting taxes. This lasted but a few months, when he was employed by Luman Watson, a maker of organs and wooden clocks in Cincinnati. In the workshop of Mr. Watson he found tools and facilities for indulging his eager fondness for mechanics. His skill soon drew to him the most delicate work in the construction of organs, that of making and trimming the stops. . . .

During the two or three years that he was with Mr. Watson, he invented several improvements in clock machinery. . . . When about twenty-one years of age, he became acquainted with a Mr. Eckstein, a German sculptor, who got him to assist in casting some busts. Now he first witnessed the process of modelling in clay. Before this he had modelled in wax some small bas-relief likenesses. Shortly afterwards he undertook to make in wax, the size of life, the bust of a little girl four years of age, the daughter of John P. Foot, of Cincinnati. Of this his first bust, made in the garret of the clock-factory, by the side of his bedroom, Thorwaldsen, on seeing a cast of it in his studio in Florence, said that it was the work of a master.

The mind of Powers was now strongly drawn from the path of mechanism into that of the art of sculpture thus suddenly opened to him. He felt that this was his calling. His second work (modelled out of the same material as the first) was a copy, reduced size, of the head of the Venus dei Medici, from a cast (of the head alone) lent to him.

His next employment was as assistant in the Cincinnati Museum. Here he began by making a head to represent a cannibal of the Caribbee Islands. Out of a common wax figure he worked up a monster that brought in much money to the museum. He made also other wax figures, some of them likenesses of known individuals, that caused admiration and astonishment by the resemblance. He contrived a representation of the infernal regions, in which he played at first the chief part, that of Beelzebub, placing himself in connection with a powerful invisible electrical machine behind the grating, whence with a long wand he would, in the darkened room, suddenly transmit a shock to the alarmed spectators.

He was now frequently told that he ought not to waste his life in such employment, but that he should go to Europe and study sculpture. But he had not the money needed to carry such a plan into effect.

He had been in the museum about two years, when he accepted from Mr. Longworth, of Cincinnati, an offer to supply the means for his spending some time in Italy; and he went to New York to take ship. The plan failed on account of an informality in the letter of credit, and he returned to Cincinnati and to the museum, where such prospects were held out to him as induced him to give up for the time the voyage. He did not regret in after life the failure, at that early period, of the scheme to study abroad, alleging that he might have been misled in the schools of Italy into a vicious path of art; whereas by having remained longer at home, and there studied nature intently in making many busts, he became proof, through this wholesome discipline, against the errors and artificial doctrines and practices of European Academies. . . .

His kind friend, Mr. Longworth, now offered to furnish the means for him to go to Washington, to try there to get such orders as would enable him to proceed to Europe. Accordingly he quitted finally the museum, where he had in a measure wasted seven years of his life, having in all that time executed but three busts, and done nothing else that directly furthered him in the art for which he was by nature destined. Before leaving the museum, he married, on the 1st of May, 1832, Miss Elizabeth Gibson, of Cincinnati.

In 1833 he arrived in Washington, provided with letters to some of the leading public men. Several of them declined to sit to him, even without charge. Others not only allowed him to take their busts, but treated him with kindness and encouragement, particularly Colonel Preston of the Senate, and Mr. Calhoun. He took the busts of Gen-

eral Jackson, Mr. Calhoun, and Colonel Johnson. The following session he returned to Washington and took others. In the summer he went to Boston, and came back to Washington in the autumn. He now got a few orders for busts, but these would not have enabled him to go to Italy. That he could do so at this time, was owing to the kindness of a Southern gentleman, Colonel John Preston, of South Carolina, who offered him whatever amount was required to enable him to establish himself in Italy. Accordingly in October, 1837, he sailed with his family from New York for Havre, and passing through Paris arrived in Florence in November.

Having traced the progress of the subject of our memoir through the struggles and vicissitudes of early life until his entrance into a more congenial field, it may be well to say a few words as to the condition of sculpture in Italy at the time of his arrival, particularly as respects the art of portraiture, which was, at that time, his especial pursuit.

From a variety of causes, which want of space will not enable us to declare, through the influence of Bernini, Canova, Thorwaldsen, and Bartolini, bust-making had so far degenerated that a pleasing general expression, with sufficient likeness to be recognized, was all that was expected. If the sitter was satisfied, the sculptor was content; for portraiture was considered rather as the means of pleasing patrons of more considerable works, upon which the artist founded his expectations of reputation and fortune, than as lending any permanent benefit. Pecuniary emolument was the chief incentive to that kind of exertion. Our artist had been so long fed upon the husks of mechanical work that he came with a keen appetite to the simple but sweet bread of nature. To him it was luxury, the liberty of reproducing the features of those whose interest in his success won a title to his gratitude; and his strong common sense taught him that no change of organization, however flattering, would compensate for the loss of truth.

The consequence was that his portrait busts were beheld with surprise and admiration by those artists and amateurs who saw them, and their fame was spread so wide and rapidly that he soon found employment.

Thus the predictions of his friends were satisfactorily realized. He not only finished in marble the casts which he carried to Florence, but modelled other heads, and found time to produce a study model of a statue of Eve, then, in 1840, the large-sized model, the first study of the entire figure that he had made.

The first statue of Powers which attracted much public attention was the Greek Slave. This was finished in marble, with great care; and, although criticisms of its composition were not wanting, its excel-

lent proportions and sweet surfaces fully account for its becoming a public favorite. The subject enlisted the sympathy of the spectator, and it won the applause of the most opposite characters. Exhibited throughout the United States, and afterwards at the Great Exhibition in England, it carried the fame of its author far and wide, besides placing him in a better position as regards money matters.

Other works followed in uninterrupted if not rapid succession. The Fisher Boy, America, California, a statue of Calhoun and one of Daniel Webster, together with numerous busts, attest his industry.

Powers's mechanical ingenuity was very useful in the production of new tools and rasps for the finish of models and marbles. Indeed, he invented such an excellent perforated rasp for plaster, that, fascinated by its adaptability, he worked out all his later statues in that material, saying that by so doing he saved not only the tedium of covering and uncovering the clay models, but the expense of casting. His example, however, has not been followed, as the loss of time in fashioning so irresponsive a material as plaster makes it a poor exchange for clay, which is docile, and quick to receive a thought. It is worthy of remark that in bust-making Powers retained the use of clay. Among the works which have the most added to Powers's reputation is his bust of Proserpine. The name of course has no significance, except as indicating the character of maiden loveliness that he wished to portray; but in it he has succeeded in imbuing the Greek type with a feminine sweetness, rare in the classic marbles. This work, often repeated, with its rich accessory of acanthus-leaves, is perhaps the most ideal creation of the artist.

The character of Mr. Powers's life-long friends is an index to his own. Living in a city not renowned for its moral tone, and pursuing an art in which various temptations, personal and material, are apt to assail, we are not aware that a shadow of suspicion ever attached itself to his purity. He was a thoroughly honest man. It is rarely given to men of eminence to be without enemies, and Powers's disposition was not one that could easily brook affront. How much his "Indian blood" may be responsible for some of the skirmishes in which from time to time he was engaged, we will leave for the physiologist to decide. It is pleasant to believe that his last days were serene and tranquil. Surrounded by a loving family, cheered by the wife of his youth, and ministered to by all that the affection of friends could supply, he passed away at Florence on Friday, 27th June, 1873.

Jean Victor Poncelet was born at Metz, July 1, 1788, and died in Paris. He was admitted to the Polytechnic School in 1807, then to "l'École d'Application" of Metz, in 1810. He entered the corps of engineers with the grade of lieutenant in 1812; took part in the Russian campaign with the forces of Marshal Ney, and was made prisoner at Krasmoe. Here he was subjected to many privations, by which his health was much impaired. The result of the mathematical researches that were made while he was a prisoner were published in the "Annales de Mathématique."

At the fall of the empire, he returned to France, and was for fifteen years professor of mechanics at Metz.

Before leaving his native city, he gave a gratuitous course of lectures on applied geometry to the young workmen of the town.

The very valuable papers on geometry that he addressed to the Academy of Sciences were the cause of his appointment as a member of that society in 1834. At about that time he left Metz, and went to Paris, where he became professor in the "Collége de France."

In 1845 he was appointed colonel of engineers, and in 1848 he was general of brigade and commander in the Polytechnic School.

At this time he was chosen, by the people of Metz, to represent them in the Assembly. He there voted with the moderate democratic party.

In 1851 he was president of the "Scientific Commission of the London Exhibition," and in 1853 was enrolled in the Legion of Honor.

By his works on hydraulics he has rendered great service to industrial art. But it is especially as a mathematician that he held a high rank; for he was one of the most eminent representatives of that school of geometry that may be called "l'École de Monge," and which had in its ranks Carnot, Servois, Chasles, Dupin, &c.

His published works and scientific reports are numerous, and upon a great variety of subjects, embracing many original investigations resulting in new conclusions. These remain as monuments of his great powers and high attainments.

"He was a profound geometer, a skilful inventor, an eminent teacher, a sagacious engineer, an original writer. He was a true man, rigorously faithful to his duties, severe to himself, full of sympathy for the weak and the oppressed, of tried loyalty and ardent patriotism. He may have had rivals, he never had enemies or detractors."

Dr. P. C. H. Louis was born April 14, 1787, in Champagne, at the village of Aï (Marne). His father was a vine-growing proprietary farmer. His mother was a woman of intelligence and energy. She

early influenced the character of our great associate. It was from her that he inherited that gravity and at times sternness of manner noticed in after life. His father died in consequence of exposures during the horrors of the Revolution. By the kindness of an old priest, young Louis was enabled to pursue at Aï a part of his classical studies. They were finished at one of the seminaries of Paris. On leaving college, he began to study law; but he soon gave it up, in order to devote himself to medicine, which he commenced to study in 1807. After spending one year at Rheims in the office of a surgeon, he returned to Paris, and there finished his studies.

In 1813, when twenty-six years old, he presented his Thesis and received the diploma of Doctor of Medicine, and immediately took rooms at Paris in the fashionable quarters of St. Honoré. Soon afterwards, having lost one who had been to him a protector and friend, he determined to leave France, and at first thought of going to Constantinople. While doubting what locality he should choose, a friend of the family, the Governor of Podalia, proposed that he should accompany him to Russia.

Louis accepted the offer. He resided several years in that country. The latter part of the time he was settled at Odessa, and met with a brilliant success, being sustained by those in the highest rank of life. He received from the imperial authorities the title of Physician to the Emperor. Thus occupied and entirely successful, he spent four years, and at the end of that period he was at the zenith of his fame as a practising physician. In 1820 (aged thirty-three) a terrible epidemic among children swept over Odessa. Louis was in despair at finding how powerless he was to save life; and, after the epidemic had ceased, he felt it his duty to return to Paris, in order to study all that had been learned about the treatment of children's diseases during his long absence. He supposed that great advances had been made since his departure from the metropolis. Arrived at Paris, he studied six months at the Children's Hospital, but found that he learned nothing new there. The celebrated Broussais, with his fiery eloquence and furious treatment of all opponents, was at that period in full vigor of intellect, and at the height of his world-wide fame.

Louis, while won somewhat by Broussais' specious and fervid method of enforcing his doctrines in regard to inflammation and its effects, could not be persuaded that a careful scientific study of the facts of disease would necessarily lead to such conclusions as those announced by that master-spirit of the medical school of that period. Desirous, however, of knowing accurately the doctrines of Broussais, he studied

for some time in Broussais' wards, justly thinking that he would be better able to understand those doctrines if he heard them from the master's own lips. Broussais' scorn of the results of ancient medicine met with a cordial response from Louis. But the substitution of still another theory, instead of the results derived from well-observed and minutely recorded facts, was wholly contrary to Louis' severe ideas, his *besoin de la verité.**

This method of investigating medical subjects being very different from that pursued by Broussais, Louis, from the very necessities of his nature, soon became one of the most formidable opponents of the whole theoretical school of medicine. Violent attacks were made upon him by the seemingly all-conquering Broussais. In order to make up his mind more definitely, and although already thirty-four years old, Louis decided to resign medical practice, and to devote himself for a certain number of years to the unbiassed observation of disease.

This he did for six years, in the wards of his friend Chomel, at that time Professor of Clinical Medicine at La Charité.

He spent from three to five hours each day at the hospital. At least two hours were occupied in making each autopsy. He examined every organ in every dead body, even if no symptoms had been connected with those organs so examined. "The two wards of the hospital, the autopsy-room, and the small apartment in the *entre-sol* of the hospital which were granted to him by the authorities, were all Paris to him." "He became a true scientific cenobite." † "As such, he was often exposed to expressions of surprise and pity from students and physicians, so that it required some courage to meet them with perfect equanimity." In this way he recorded accurately, by the bedside and in the autopsy-room, two thousand observations. Out of these he began, at the request of his friend Chomel, to publish in 1823–4 certain memoirs and monographs. Two years afterward, 1825, he printed his important work on Phthisis. This obtained for him a place in the Academy of Medicine, and fame throughout the civilized world. In 1826 his researches on Typhoid Fever were put forth. In the preface he replied to his critics by quoting Descartes's remark "that

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* In the latter part of his life he gave as an autograph the following: —

"Il y a quelque chose de plus rare que l'esprit de discernement. C'est le besoin de la verité; cet état de l'âme qui ne nous permets pas de nous arrêter dans les travaux scientifiques à ce qui n'est que vraisemblable et nous oblige à continuer nos recherches jusqu'à ce que nous soyons arrivés à l'évidence."

† Dr. Louis, Sa Vie, ses Œuvres, par E. Weillet, membre de l'Académie. Paris, 1878.

we should regard almost as false what is only probable and not founded on fact."* These and other works of Louis were received everywhere with delight, except by those who could not tolerate, or at least could not appreciate, the beauty of strict deductions from facts.

On the continent of Europe, in England and in America, Broussaism struggled hard, but finally succumbed under the influence of modern science. Louis, a direct scientific descendant, if I may use that expression, of the great John Hunter, of England, was the file leader in medicine, of this great change. He counted his cases and the symptoms in each, and stated the results in a definite manner. These facts must always remain true, although different interpretations may hereafter be made of some of them.

His pupils were not numerous; for he had no grace of speech like his friend Chomel, no fiery eloquence like Broussais, no brilliant powers of classification as shown by Andral. On the contrary, he was severely rigid in his strict deductions from data collected without bias. Moreover, to the majority he seemed rather severe in manner; but his works had no mannerism. They carried conviction to the minds of readers in all countries, from the very sternness with which their author rested on the firm foundation of fact. Each book carried with it, and always will carry with it, its own proof.

The future historian of medicine, when he seeks for the guiding medical minds of this century, will find Louis in the foremost rank. This method of writing medical books had been tried imperfectly before. The fame of Morgani, and that of some others, rests upon it; but never before had the medical profession seen it so clearly exhibited as in the Numerical Method pursued by Louis. By his works, and still more by his living example, he founded a School of Observation, which spread in Europe and America. Even his opponents were finally compelled to cite their facts, and, to a certain extent at least, to give numerical results, in order to win a belief in their statements.

In 1828 Louis was chosen by the French government to go on a commission with two others to Spain, to study the Yellow Fever. While there he was seized with the disease, but escaped fortunately without injury. His report in manuscript remained unpublished, until Dr. Shattuck, of Boston, was allowed to publish a translation of it. The original was finally published, with an edition of Louis' works, in Paris. Having finished the analysis of his cases, he resumed practice.

* While preparing these works, he spent a year at Brussels in quietly tabulating his cases.

He was connected for twenty-five years with the hospitals, either with La Pitié, Hôtel Dieu, or Beaujon. His works made him famous; and at the age of forty-eight he was consulted by persons from all quarters, as the first living authority on the diagnosis of disease, especially of thoracic disease. Not until forty-five years old did he meet the excellent lady to whom he was subsequently married. She was the sister of the famous Victor Hugo. She survives her husband, to whom she was most tenderly attached. Their marriage was a most happy one. They had one child, a son, who died of phthisis at the age of eighteen. He was a charming youth, and the delight of his parents. Louis was overwhelmed with sorrow, and never wholly recovered from the blow. He resigned his place at the hospital, and travelled south with the youth. He made no complaint after the death, but resigned most of his labors. He however retained a warm interest in all the new and thorough researches in medicine, and his heart under suffering seemed to blossom out and produced a sweetness of manner hardly known before.

To his young medical friends he was always ready to give counsel, and not a few times he offered to them large loans of money to enable them to publish their works, taking their notes as his only security. In at least one instance he was known to have burned up such notes after the death of the author, because he was unwilling to burthen the poor man's estate. To those of us who knew him intimately, and had become aware of how much he would do for friendship's sake, this incident seems most natural.

Combined with all these noble and beautiful traits of character, Louis was one of the most modest and simple of men. He sought no honors. He declined the title of Physician to the Emperor Napoleon. He resolutely refused to take any of the usual initiatory steps to become a member of the Institute of France, for which he might have offered himself with the certainty of success.

Such is a brief history of Louis as a scientific student of medicine, as a practising physician, and as a man. We have seen him a leader of modern medical thought. He was so, because he was in accordance with the spirit of modern science and methods of investigation. He was, moreover, inspired to bring medical learning and art into accordance with science. In furtherance of that desire, he was willing to devote long years of the most important part of his life to patient and truthful investigation, even if in so doing he gave up hope of gain, and met usually with indifference or open ridicule, and sometimes abuse.

These are the elements of a true greatness of soul, and in choosing

him long since as one of our associates we honored ourselves more than we honored him.

He lived until his eighty-second year, retaining his tall erect form and fine head until the last. He died June 9, 1872, after about two months of suffering nobly borne, beloved and respected by all, retaining his mental faculties clearly till the last, and serene in his beautiful and firm faith in the "Good God,"* who, as he believed, governs all things aright.

I cannot conclude this sketch better than by quoting the closing passages from the address already alluded to (Weillet): "Such was the life, full of supreme devotion to science, to professional duty, to family, to friendship, showing an uprightness and probity without blemish, an indefatigable energy in the search after truth, and leaving after it in the world of science brilliant traces of its passage, as indelible as the regrets which it has left in all loving hearts."

Gentlemen of the Academy, by a happy coincidence I find that this day of our meeting † is the anniversary of Louis' birth, eighty-seven years ago. In these brief records of his life, I have wished to present to you the portrait of a great and good man; a devoted lover of the truth; and a noble, religious soul. If I have failed in graphically presenting to you that picture, so that you can ever bear it with you as an example of devotedness and of self-sacrifice in the cause of truth and of science, it is because of my imperfect use of language, which prevents me from conveying to you an adequate idea of my love and veneration for our great associate, my most honored master in medicine, and one of the dearest friends of my adult life.

PHILIPPE EDOUARD POULLETIER DE VERNEUIL was born in Paris the 13th of February, 1805. Destined for public life, he became a page at the court of Charles X., and afterwards occupied a position in the Department of Justice till 1833. The events of 1830 turned his thoughts from politics, and he began from that time to pay considerable attention to scientific pursuits. He became interested in geology, from attending the lectures of Elie de Beaumont. He became

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* "Croire en Dieu! Mauvaise expression qui ne dit ce qu'elle doit dire. . . . Croire en Dieu? mais on ne croit pas au soleil; on le voit, on le sent. Dieu! est-il moins évident que le soleil? J'ai confiance en Dieu. Si je pense à lui, j'espère; et mes espérances ne sont pas dominées par la terreur. Dieu est notre Père. La bonté est un de ses attributs essentiels." — *Manuscript Notes.*

† This notice was read to the Academy at the meeting of April 14, 1874, by Dr. H. I. Bowditch.

a pupil of Des Hayes, who directed his paleontological studies, and who gave a marked bias to his subsequent career by infusing him with his zeal for the paleontology of invertebrates. In the field of fossil invertebrates from the secondary period, De Verneuil stood, when in his prime, without an equal. Being independent in his circumstances, he was able to spend a great part of his time in geological explorations in the field. His first studies were made in Wales. Subsequently he visited the Bosphorus, the Danubian provinces, and in 1836 he made an exhaustive exploration of the Crimea. In the published Reports of these journeys, his pre-eminence in paleontology soon became apparent. From 1840 to 1842 he spent all his time, associated with Murchison and Keyserling, in the extensive explorations of the Russian Empire, from which he established, in connection with his colleagues, the identity of the deposits of Russia with those of Western Europe. The most important feature, however, of this great exploration, was the introduction of the Permian system in our geological nomenclature.

In 1846 he spent six months in the United States, where he attempted to establish the first parallelism between the deposits of North America and Europe, and thus extended to the two worlds the general parallelism he had helped to establish between the strata of Eastern and Western Europe.

From 1850 to 1866 he took part in several geological explorations of Spain, in company with Columb, De Lorière, and Ernest Favre. The result of their explorations was an excellent geological map of Spain, at that time in geology a *terra incognita*. During the last ten years of his life he made many excursions to Vesuvius, and at the time of the last eruption incurred considerable risk to obtain the possible solution of some problem in which he was interested.

In 1854 he was elected a "membre libre" of the Académie des Sciences. De Verneuil was three times chosen president of the French Geological Society, in 1846, in 1853, and in 1867. His independent position, his entire unselfishness and devotion to his favorite science, gave him an exceptional place among his scientific associates in Paris. As a fit closing of a life devoted to scientific pursuits, in which he had attained great distinction, he left his paleontological collections to the École des Mines. This collection is almost unique. It was brought together from his extensive travels, and, containing as it does the types of all the fossils he described, its value as a monument of the early history of paleontology is very great.

Michel Chasles was born at Epernon on the 5th of November, 1793. At the age of twenty he commenced a series of investigations upon surfaces of the second degree, which almost immediately gave him an European reputation; and for sixty years he published memoirs which placed him in the foremost rank of geometers. He was the last and not the least of the constellation of French geniuses who have given to transcendental geometry its finest precision and most elegant expression. He was a master amid such names as Carnot, Monge, Meusnier, Poinsot, Dupin, Poncelet, Fresnel, Olivier, and Liouville. In his discussion of the attraction of ellipsoids, and his simple and ingenious development of the theory of the electrical shell, he was original in his form and mode of inquiry, and was scarcely anticipated by Greene and Gauss. The immense value of such researches has been recently exhibited by Maxwell, who has shown that the path of integration has coincided singularly with the profound ideas upon the nature of electrical action developed by Faraday. There is not in the history of physical science a more interesting correlation of thought between observation and theory, nor one more worthy of the attention of philosophers.

The labors of almost every great mathematician have been permeated by some one leading idea, which, however small it may seem in its general state, has grown in the fruitful soil of an original mind into a comprehensive theory. It was so with Chasles. His attempts to force geometrical demonstration from the variety of cases which embarrassed the ancient geometer, and to generalize them all into a single argument in a purely geometrical form, and without resort to the algebraic symbol of negation, culminated finally in his "Superior Geometry." This department of mathematics is now cultivated to such an extent, that it is endowed with a distinct chair in the fully equipped university.

By a happy rebound of his elastic mind, Chasles was led in the opposite direction to the curious problem of reproducing a lost work of an eminent ancient geometer. *The Porisms of Euclid* were considered to be the most original and profound of his productions, and its loss was greatly regretted. All that remained was a very indistinct account by Pappus, and a loose description of the nature of a porism given by Proclus. With the exception of a happy divination of the definition of a porism by Simpson, and a nice example, Chasles had nothing to guide him but his own geometrical instinct, and the almost unintelligible description of Proclus. But his effort was successful beyond belief, and the words of Proclus apply to it with the

same precision with which the plaster of the sculptor fits his model. This is an unique undertaking; and if, whenever the original may be rediscovered, it should prove to differ materially from the reproduction by Chasles, it will be more wonderful than the difference between the true orbit of Neptune and the prediction of Leverrier.

Chasles has exhibited the power of profound scholarship and generous criticism in his reports upon geometry, and especially in his "Aperçu historique sur l'Origine et le Développement des Méthodes en Géométrie." His researches led him to the conclusion that the popular idea of the Arabic origin of our arithmetic is erroneous, and he has given a very able and ingenious argument to establish and trace its Pythagorean origin and descent.

In the seventy-fifth year of his age Chasles seemed to have experienced a strange form of insanity, which was caused by poison infused into his too credulous ear by a miserable impostor. An accomplished scholar, he was persuaded to embark a large property in the purchase of manuscripts which were palpable forgeries. Is not this insanity? And what but insanity would have induced the belief that he had veritable manuscripts of Julius Cæsar and of some of the Apostles? What but insanity would have maintained his pertinacious belief in the authenticity of his manuscripts, after the wretch had confessed the villany? What but insanity would have induced the first geometer of France to soil the immortality of Newton?* To the honor of France be it said that the attack upon the English geometer found no sympathy there; but, on the contrary, while the forgeries were read before the Academy, the colleagues of Chasles hid their countenances with grief, at the dark cloud which had obscured this brilliant intellect.

Chasles was a polished gentleman as well as a scholar and a geometer; and he cordially extended his hospitality to all the cultivators of his science who visited Paris.

By the death of Baron WILHELM VON KAULBACH, at Munich, on the 7th of April, Germany has lost the last of three artists who enjoyed a world-wide reputation. Two of them, Overbeck and Kaulbach, were Honorary Members of the American Academy, and as such have a claim upon the interest of its members. The claim of Overbeck has been already acknowledged by a notice written at the time of his death, in

* One of the finest chapters of the comprehensive review of Mathematical History contained in the "Aperçu Historique" is a grand homage to the genius of Newton.

which he was spoken of as the reviver of mysticism in art, taking his inspiration from the Pre-Raphaelite painters and from Rome. The present paper is intended to discharge the same debt to Kaulbach, the originator of a species of monumental art in which the philosophy of History and the subtilties of Allegory played a conspicuous part, and a satirist of remarkable ability. He was the pupil of Peter Cornelius (the third of the artists referred to above), the father of that revival of art in Germany which had King Louis of Bavaria for its patron, and Munich for its chief centre.

This revival did not bring about the hoped-for results, because its basis was purely artificial. It owed its existence to personal effort, and to the powerful support of a Prince who tried to galvanize spent forces into life, and though the dead eyes opened, and the stiffened limbs moved under the magnetic current so long as it acted upon them, they relapsed into rigid stillness when the motive power ceased. For half a century Cornelius was the guide of those who aimed at giving art in Germany that social influence which it had exercised in ancient Greece and in the Italy of the Renaissance. It was not to be the slave of fashion and the minister to private luxury, but the universal and mighty interpreter of moral and religious ideas as taught in history and sacred writ. These were to be painted on a gigantic scale, where all men could see them, — in churches, halls, palaces, and museums. But though Cornelius and Kaulbach were both men of high purpose, commanding talents, and inflexible will, they failed to give art the position which they wished it to take, for it was not a natural growth of the time, expressive of its ideas and tendencies, like the art of Giotto and Raphael and Michelangelo. Their object was not artistic, but didactic. They considered themselves to be teachers in art, and painted not for art's sake, but with a moral purpose, thus placing that second which should have been first, making that the cause which should have been the effect. From such as these, says Swinburne, shall be taken away even that which they had at starting.

Brought forward by Prince Louis of Bavaria, on his return from Rome, as the painter who was to be to him and to Munich what Raphael had been to Leo X. and to Rome, Cornelius gradually lost his hold upon public favor (which had been showered upon him, until he chilled it by his mannered and artificial frescoes at the Glyptothek, and his overcrowded and ineffective painting of the Last Judgment for the Church of St. Louis), had the mortification of seeing his best pupils, with Kaulbach at their head, turn from him to found a new school whose principles were in opposition to his own, and never fully

regained his first position, although he afterwards played a conspicuous part at Berlin. Like the one soldier who perished in the famous Italian battle under the condottiere Piccinino, in the fifteenth century, — not by a sword thrust, but by the weight of his armor, — so the art of Cornelius and Kaulbach struggled under the oppressive burden of mediæval machinery and of allegory, into whose mysteries this busy world has no time to penetrate.

Wilhelm von Kaulbach was born at Arolsen, in the Principality of Waldeck, A.D. 1805. He was the son of a goldsmith, who finding great difficulty in maintaining his family, on account of the disturbed condition of the times, removed shortly after the boy's birth to the small town of Mulheim on the Ruhr, where he hoped to find easier conditions of existence. Here the young Wilhelm grew up, not only without showing any artistic tendencies, but having, it is said, a positive disinclination for the study of art. This, however, disappeared under the impression made upon him by some engravings illustrating the principal scenes in Schiller's tragedies. They inspired him with the wish to become a painter, and his father, who approved of his resolution, having consulted Rauch, the eminent sculptor, sent him to Dusseldorf at the age of seventeen, to study under Cornelius, then (1822) Director of the Academy.

In some respects Kaulbach was fortunate in his master, whose instruction reposed upon just and elevated principles. He insisted upon a careful study of the nude, and a close observation of nature, and recommended independence of thought in treating subjects taken from the works of the poets, but attached too little importance to technicalities, and undervalued beauty of execution. Under his direction the students of the Academy went through a severe course of study. They were obliged to make elaborate and highly finished studies from the antique and from the nude, as well as to copy every fold and wrinkle of the linen draperies and thin woollen cloths which were bound over the limbs and torsos of casts. These they afterwards reproduced from memory, with subsequent reference to the model as a test of their accuracy.

Among the students were Sturmer, Stilke, Eberle, and Schorn, to whom, soon after Kaulbach's arrival, were added Ch. Hermann, of Dresden, and Ernest Förster, of Altenburg. Kaulbach became very intimate with the two latter, and with Mossler, one of the professors at the Academy, who encouraged and assisted him in his labors. A small pension was granted him by the Prussian government in 1822, and he was appointed to paint a series of frescoes designed by Cornelius, in the Hall

of the University at Bonn, aided by his friends Hermann and Förster. Dissatisfied with his own share in the work, he seriously thought of renouncing painting as a profession, and of gaining his livelihood as a teacher of drawing. Better counsels, however, prevailed, and when, in 1825, Cornelius became Director of the Academy at Munich, Kaulbach followed him with his fellow-pupils. Before leaving Dusseldorf, he visited the Lunatic Asylum, under the guidance of a doctor connected with the establishment, and received from him a great deal of information about the unfortunate patients. The deep impression which this visit made on his mind showed itself in one of his most celebrated works, "The Narrenhaus," which he painted at Munich in 1828 from studies made on the spot. This painfully realistic representation of one of the most melancholy scenes which human eyes can rest upon gave him a European reputation. The picture was engraved by H. März, and lengthily discussed in a volume written by Guido Goerres, the son of the poet, in which, like a true German, he explains it as an allegory. This is an error, since its truth to nature is its chief merit, as it is its chief defect, for were the subject treated allegorically it would be less objectionable. From the surly jailer, with his pipe in his mouth and his keys jingling at his back, through the whole crowd of vacant, sorrowful, suffering, imbecile, and maddened unfortunates, who sit, stand, or struggle together in the prison-yard under his eyes, it is all stern, sad truth.

Kaulbach's first works at Munich were the frescoes in the arcades of the Hofgarten; a mural painting of Apollo and the Muses, in the Concert Hall of the Odeon; and subjects from the fable of Cupid and Psyche, in the palace of Duke Max. Von Klenze, who took him into favor, also obtained for him a commission to paint twelve subjects from Klopstock's "Arminius," in the Queen's Throne Hall.

Any one who has seen these frescoes will remember the confused impression which they leave upon the mind. Amid the crowd of forms in mannered and violent action, there is much that would be effective, were there repose anywhere. There is strenuous thought and vigorous drawing, but no contrasted gentleness or beauty, which last may be said to be unknown to German artists, from Meister Wilhelm of Cologne, down to the painters of the present time, with perhaps the exception, to a limited degree, of Bendemann, Hess, and Overbeck. In Italy, the feeling for beauty expresses itself in plastic and in pictorial art; in France, taste, which is one of the attributes of beauty, is seldom wanting; in Germany, character and energy of expression are seldom softened by æsthetic charm. If Kaulbach can be said to have

ever realized a beautiful type, it is in some of the children which he painted in the friezes of the New Museum at Berlin, or in some of his illustrations to the fairy tales published at Stuttgart; but among his thousands of adult figures we do not remember one which we should call beautiful, either from the Greek or the Italian point of view. Like Cornelius, he wanted a clear comprehension of the limits of his art; he had not pondered enough over the "Laocoön" of Lessing, where the lines which separate painting from poetry are so clearly defined. He painted from the poets' verses, as if painting were as unfettered as poetry. Such, assuredly, is not the case. The painter must limit his expression of sentiment, so that it may never trouble the harmony of his work. Take, as an example, these verses from the lament of the Bards over Arminius, in Klopstock's third Herminiad, which Kaulbach treated in those frescoes in the Queen's Throne Hall of which we were just now speaking: —

"Here, O bards, upon this rock covered with hoary moss let us sit and sing our funeral hymn. Here stay your steps; let no one peer beneath those branches which cover the mortal remains of our country's noblest son. He lies there bathed in his blood, — he who, when the Romans with war-dances and hymns of triumph led his Thusnelda captive, filled their hearts with a secret dread. Behold the torrent rushing down the mountain side, to precipitate itself upon the rocks below. Its tumid waves are black with the up-rooted pines. Hurrying on in its swift course, it comes to bring them for the hero's funeral pyre."

To realize the images which the poet here calls up in our minds in a few lines, the painter, who feels the exigencies of his art, must treat them successively. Unlike the poet, he cannot have prepared us to understand them by a previous recital of the brave deeds of his hero: he can strike but one blow, seize but one pregnant moment. The bards gathered in the gloomy German forest to lament over the body of the dead chieftain, which lies hidden under the heaped-up branches; the torrent hurrying on to bring the black pines torn up by their roots to feed the flames which are to reduce it to ashes; the captive, Thusnelda, led with festal dances and songs of victory before the eyes of the Romans, who vainly strive to forget that Arminius lives and may yet avenge her shame, — all appear before us as we read Klopstock's lines. Our thoughts follow his from barbaric Germany to imperial Rome. We see Thusnelda as she was and as she is; we know Arminius in life and in death; we hear the bards lament, and the triumphant songs of the Romans, — nay, we even look into their hearts, and perceive the secret dread of the future which lurks beneath their

apparent joy. Such power to compress *multum in parvo* the painter has not; and here we come to the capital mistake of painters like Kaulbach, who endeavor to paint as poets write, and crowd into one composition a multitude of incidents, expressed by groups and single figures, with but little observance of those unities which, however questionable as necessities in poetry and the drama, are indispensable in pictorial art. "Where did all these persons come together?" said some one to Kaulbach, while looking at one of his great pictorial histories at Berlin. "In our memory," he answered, thus giving us the clew to his heterogeneous system, which was eclectic in principle, and based upon the strained association of things which, when brought into unwonted companionship, obstinately stood apart, and refused to be welded into a harmonious whole.

As Kaulbach rose in public esteem at Munich, the breach between him and Cornelius widened, until at last the pupil broke away from his master, and founded an art sect of his own. The Academy proclaimed that in a work of art the idea was all in all; that color and execution were of comparatively little importance; and that the true style was to be found in the special forms born of the artist's genius, or, to use a consecrated phrase of a peculiarly Teutonic flavor, that it lay in forms "evolved from the depths of the artist's inner consciousness." The new school professed to take nature as its guide, and to aim at technical perfection. How far it really followed its own doctrines is a question. It was apparently the old battle between the Idealists and the Realists: really, however, these names can hardly be given to either party, so far did they fall short of their respective aims. Filled however with the conviction of his special mission, Kaulbach withdrew himself more and more from society, and worked on with ardor in his studio in the suburb of St. Anne. In 1828 or 1829 he painted the Narrenhaus, which has already been mentioned. Then followed the Battle of the Huns (*Hunnen Schlacht*), which greatly contributed to his reputation, and which is certainly the most striking of his great works.

The subject is taken from a mediæval legend, which commemorates the battle between the Huns and Romans before the gates of the Eternal City. The spirits of the dead warriors rise above the battle-field to renew the combat in mid-air. Alaric, standing upon his shield with a torch in his hands, leads on his phantom warriors against the shadowy Roman hosts, who are divided from them by a straggling mass of figures, men and women, Huns and Romans, fighting with all the energy of despair. Below, in the background, the walls and towers

of Rome rise pale against the sky; heaps of slain fill the middle distance; and the foreground is occupied by the dead and dying, and by a group of women, who are swept upwards as with the blast of a mighty wind, to join the aerial combatants. Kaulbach had laid in this subject upon his canvas in black and white, when it was seen by a Polish nobleman, Count Raczinski, residing at Berlin. Struck with its power, and convinced that Kaulbach's color would rather mar than improve it, the Count purchased the unfinished picture and placed it in his gallery, of which it still forms the great attraction. Long after, Kaulbach repainted this in the New Museum at Berlin.

It was, we believe, by the advice of Count Raczinski, that he now determined to visit Italy, in order to study the works of the great colorists. He remained some time at Venice, and spent a twelvemonth at Rome, whence he returned as little capable of using color effectively as before. This is not to be wondered at. A man may develop a feeling for color; but if Nature has not implanted it in him the effort to attain it is useless. A man is born with an eye for color, as he is with an ear for music; and if the eye or the ear be defective, no looking at the works of Titian and Veronese, or listening to those of Mozart or Beethoven, will give him the one or the other. On Kaulbach's arrival at Munich, King Louis made him his Court Painter, and would not allow him to accept the directorship of the Dresden Academy which was offered to him by the King of Saxony. The applause which greeted his next work, the Entry of Titus into Jerusalem, was loud. The King of Prussia in vain requested to have a duplicate, and then invited the artist to decorate the walls of the New Museum at Berlin with six great compositions, of which it was to be one.

Kaulbach began to paint them in 1845, and completed them only a few years before his death. Like Raphael at the Vatican, he accompanied each with a single allegorical figure, serving as its epigraph, and with many symbolic figures and arabesques, whose hidden significance could only be adequately explained in a library of volumes. These paintings are executed in stereochromy (*i.e.* solid color, *στερεὸς* and *χρῶμα*), a method of painting in which water-glass (a combination of sand, potash, and charcoal, dissolved in boiling water) serves as the connecting medium between the color and its substratum. The wall is first saturated with water-glass, and when dry is painted upon with colors mixed in distilled water. The colors are fixed by water-glass, for the application of which a sprinkler is used. The advantage of

this method over genuine fresco (which consists in the application of colors upon wet mortar) is its indestructibility; the disadvantage, that it has neither the charm of real fresco nor the depth and brilliancy of oil painting.

The subjects of the paintings at the New Museum are the Tower of Babel, the Greek World, the Destruction of Jerusalem, the Battle of the Huns, the Entry of the Crusaders into Jerusalem, and the Reformation, of which the cartoon, exhibited at Paris in 1867, is now in this country. In these six subjects, representing as many distinct epochs, the painter intended to illustrate the development of civilization. In the upper part of the Dispersion of the Races, the base of the great Tower of Babel is half obliterated by the effulgence which surrounds the Eternal, who scatters the sons of men over the face of the earth. Below, in the middle distance, Nimrod sits defiantly upon a throne, with priests beside him, and the dead and dying at his feet. The foreground is filled with groups of Aryans, Semites, and Touranians, each starting on their appointed roads. Here are the nomads of Arabia, with their flocks and herds; the idolaters, with their stone gods in whom they trust; the men of war and the men of peace, mingled together in a perplexed and confusing mass. Like the so-called music of the Future, there is much noise and little melody; a pervading agitation which wearies us with its monotony. To describe the other compositions would necessitate a repetition of the same criticisms. In all we find the same want of unity, the same arbitrary connection of things, the same detached and struggling groups; in all the same proof of laborious research and wonderful intellectual ability. Clever draughtsman, subtle thinker, deep student as he was, Kaulbach was not an artist in the higher sense of the word; that is, he was not a man in whom æsthetic perceptions were dominant. He neither soared into the region of the ideal, nor stood firmly on the solid ground of the real, but occupied a sort of cold middle ground, which satisfies neither the imagination nor the reason. He was a designer, and, as he has shown us in his admirable illustrations to "Reynard the Fox," a satirist of no common order. As such, he has been compared to Hogarth, of whose works we are told he was a great student, but this we hardly think just to Hogarth, who dealt with the vices and follies of the men and women of his time in such a masterly manner. In his illustrations to Reynard Kaulbach masks his meaning, and whips mankind over the backs of beasts, both great and small. He amuses us, calls forth our applause at his subtle rendering of his themes, but he never touches us like Hogarth, for he works with his brain rather than

with his heart, — he thinks, but does not feel, is not one of those who, by giving proof of their human feeling, make us recognize that all the world's akin. Hogarth holds up the mirror in which we see London life reflected; teaches us, as life teaches us, that sin leads to ruin, and an honest career to contentment and peace of mind. He is a great moralist, but no moral pedagogue. Thus indirectly should the artist teach us, not putting his teaching too much in the foreground, — not posing as an instructor, like Kaulbach and other artists of the school of Cornelius, but avoiding all ostentatious parade of his learning or his virtue. Ruskin, referring to the Neo-Mystics like Overbeck, says: "The German painters seem to say in their pictures, 'See how religious I am!' The French, 'How irreligious I am!'" Kaulbach, we may add, says, "See how learned I am! I have ransacked History, sacred and profane; Mythology; Poetry, lyric, epic, and dramatic. I am *omnium scibile*, and here behold I have poured out all my wealth of knowledge before you without reward." In "Reineke Fuchs" he has no such opportunity: he is an illustrator, and a very clever one, of an old German poem about those knaveries of Master Reynard which led him on to fame and fortune. His work shows a fine sense of humor, and a deep insight into character. Reynard's conceit, impudence, and shrewdness are admirably set forth. He figures in turn as pedagogue, as criminal, as hypocrite; runs through the catalogue of shams and adroit manœuvres to escape punishment, and triumphs at last as Lord Chancellor. The "Reineke Fuchs" of Kaulbach may live when the Tower of Babel, the Entry of Titus into Jerusalem, and all those acres of Kaulbach's wall-paintings are forgotten, because it has a human element in it, a genuine life of its own. We have no space left to speak of Kaulbach's many other important works, — the Battle of Salamis, the Marriage of Alexander and Roxana, the Opening of the Tomb of Charlemagne by Otho the Great, his numerous portraits of distinguished persons of his time, and his illustrations to Goethe's "Faust." Having already overstepped our limits, we must hurry to a close. Many may think that we have insisted too much upon Kaulbach's defects, considering his wonderful fertility of invention, technical ability, and intellectual acuteness. We have, however, endeavored to judge his art according to the laws which governed the immortal works of the great masters. These teach us that the object of art is beauty in form and color; that fine composition rests upon unity of design, harmony, and grace. If, then, we find these laws violated in any works of art, however otherwise remarkable, we cannot admit them into the highest company. If we have given Kaulbach too low a place on the slopes of Parnassus, others

will not be slow to give him a higher. Long after the death of an artist, the scales in which his merits are weighed continue to rise and fall as partial or impartial hands add or remove the weights, at last they settle, and a final judgment is made. This we may safely leave to posterity, convinced that in the long run every man is estimated as he deserves.

Professor P. A. Hansen has been taken away from geometrical astronomy, and terminated the labors of a distinctly marked, original, and well-rounded life, at a ripe old age. He was born in the Duchy of Schleswig, at Fondem, near the close of the year 1795, and was appointed director of the ducal observatory at Gotha in 1825. His principal contribution to science, to which his other theoretical investigations were mostly accessory, was a new method of computing the perturbations of a planet, which he regarded as especially applicable to the moon and the asteroids. His development of the perturbative function was partly numerical and partly analytic, and his memoirs concerning it are original and suggestive. There are other peculiarities of his method which deserve careful study. He does not compute directly the perturbations of the polar co-ordinates as in Laplace's method, nor those of the elements of the orbits with Lagrange's; but, for the planet's longitude, he finds a perturbed time, with which argument the fixed tables are entered. He also enters the tables of the radius vector with the same argument, and completes the calculation with additional tables for the radius vector and the latitude. Hansen applied his method to the theory of Saturn disturbed by Jupiter, to the Moon, and to some of the asteroids. His tables of the Moon were published in a handsome form by the English government, were liberally distributed to astronomers of other nations, and have been employed in the construction of the British Nautical Almanac. They are especially arranged for the calculations of an ephemeris, and the form of final interpolation is much to be commended. The resistance of the lunar motions to complete submission to known laws is strikingly exemplified in the deviations which are already detected in her path from these last and presumably best tables. But the final result will certainly be a more enlarged knowledge of the constitution of the solar system and of the laws of its changes.

Jacques Adolphe Lambert Quetelet was born at Ghent on the 22d of February, 1796, and died at Brussels, February 17, 1874. His taste for the sciences for which he was afterwards distinguished

early showed itself; and, graduating at the University of Ghent, he received an appointment there as Professor of Mathematics, at the age of eighteen. Five years later he received the degree of Doctor of Science, and the following year was called to the chair of Mathematics at the Royal Athenæum of Brussels. In 1824 he was sent by King William to complete his studies in Paris, where he prepared plans of the Brussels Observatory, which was afterwards built under his own supervision, and of which he was director until his death. In 1827–29 he devoted himself to travel, visiting the observatories of England, Scotland, Germany, Switzerland, and Italy. In 1841 a Central Committee of Statistics was established by order of the king, and Quetelet elected president, a position he held during the remainder of his life. He was the earliest to propose an International Congress of Statistics, of which the first was held at Brussels in 1853.

In looking over the long list of his published papers, over two hundred in number, we see that his attention was first directed to geometry, several articles being devoted to caustics. Soon, however, he became interested in statistics, and was one of the first to establish this subject on a firm scientific basis. This tendency towards statistics shows itself in almost all his work. In astronomy, his most important paper was a catalogue of stars having proper motion. He also began, nearly forty years ago, to observe and record meteors and shooting stars, with results which later proved of the utmost value. Meteorology, which is essentially a science of statistics, occupied much of his time; and the observations made under his direction were so complete, that it is said that the climate of Belgium is better known than that of any other point of the globe. Among other curious statistics which he collected, are those on the size and weight of man, of various nations and ages, of which the results are given in his Anthropométrie, published but a few years before his death. In fact, in statistics he appears as a great discoverer, and adding an untiring industry to the mathematical skill with which he discussed his results. He was generally called by his countrymen the Belgian Arago; and his position is well expressed by the Academy of Berlin, in a congratulatory letter on the occasion of the centenary of the Academy of Brussels, as "the founder of a new science, which proceeds from the firm basis of observation and calculation to discover and unfold those immutable laws which govern the phenomena, apparently the most accidental, of the life of man, down even to his most trivial actions."

AUGUSTE ARTHUR DE LA RIVE was born at Geneva, in Switzerland, on October 9, 1801. He was the son of Charles Gaspard de la Rive, Professor of Chemistry and Physics in the Academy of Geneva, by whom he was educated and whose tastes he inherited. His first scientific publication was on the influence of the earth's magnetism upon a movable frame traversed by a voltaic current, published in 1822, and followed by a memoir upon Caustics, which appeared in 1823. From that time forward, for a period of fifty years, he made numerous contributions to science, which were published in the "Mémoires de la Société de Physique et d'Histoire Naturelle de Genève" or in the "Bibliothèque Universelle." From 1836 to 1845 he edited the literary and scientific parts of the "Bibliothèque Universelle," which were then united. He compiled alone, as supplementary to it, the "Archives de l'Électricité," in five volumes (1841–45); and, with Marignac and others, the "Archives des Sciences Physiques et Naturelles," in thirty-six volumes (1846–57); and the "Nouvelle Période" of the same *Recueil*, in nine volumes (1858–1860).

De la Rive began his scientific labors soon after the new era was opened in the history of electricity and magnetism by the discovery of electro-magnetism, and by Ampère's electro-dynamical theory. His father had a share in this discovery, and his house was visited by others eminent in the same line of research. This may account for the preference which the son early manifested for the study of electricity, and which he continued to cultivate in its manifold relations to the end of his scientific career. Indeed, there are very few among his many printed papers which are upon other subjects. In 1840 he published an account of an electro-chemical process for gilding silver and brass, for which he received a prize of 3000 francs from the Academy of Sciences in Paris. This and other papers were deemed of sufficient value to be republished in the "Annales de Chimie et de Physique" or in the "Comptes Rendus." The principal work of De la Rive was his "Traité de l'Électricité Théorique et Appliquée," in three volumes, which appeared in the years 1854–58, into which he incorporated his theory of the cause of the Aurora Borealis, first published as a memoir in 1854, and illustrated by the experiment, now familiar to physicists, of rotating the voltaic arc of light around the pole of a magnet as any other ponderable conductor would rotate. This work, which was simultaneously published in the French and English languages, is accurate and comprehensive, and is indispensable for the scientific student of electricity.

Thus the scientific reputation of the younger De la Rive was exactly

what the father (who died in 1834, but not until after his son had become a successful Professor of Physics in the Academy) would have most desired for him. The elder De la Rive, descended from an old family in Geneva, was obliged by the political troubles of the time to leave his native city, and study his profession of medicine in Edinburgh, where he first practised it. He returned to Geneva in 1802, where his time was divided between the practice of his profession, his duties as Professor in the Academy, responsible offices in the government of his city, and the education of his two sons. Notwithstanding these various and consuming cares, he found leisure for scientific researches, particularly in electro-magnetism; and made that best of all contributions to science, viz., a son who inherited his scientific taste, and was able to devote himself exclusively to its cultivation. Although younger than Biot, Brewster, Faraday, and Davy, Auguste De la Rive was a connecting link between that select body of chemists and physicists and the present generation.

In the spring of 1873, the health of De la Rive began to fail, and he showed symptoms of paralysis. Nevertheless, he was able to prepare and read himself, though in a feeble voice, on June 5th, his annual report to the Société de Physique et d'Histoire Naturelle, the presidency of which he had resigned. Early in November he started for Cannes, where he had taken a house for the winter, with his family. On the second day of his journey (November 6), between Montelimart and Avignon, he was struck with paralysis. He reached Marseilles, where he died on the 27th of November, 1873, at the age of seventy-two, this fatal termination of his first indications of declining health having been precipitated by repeated domestic bereavements. In the world of science, and by the various scientific Academies of which he was an Honorary Member, his loss will be deplored; in his own Academy, and the city of his birth and his chosen home, he has left a void which cannot easily be filled.

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Cambridge: Press of John Wilson and Son.